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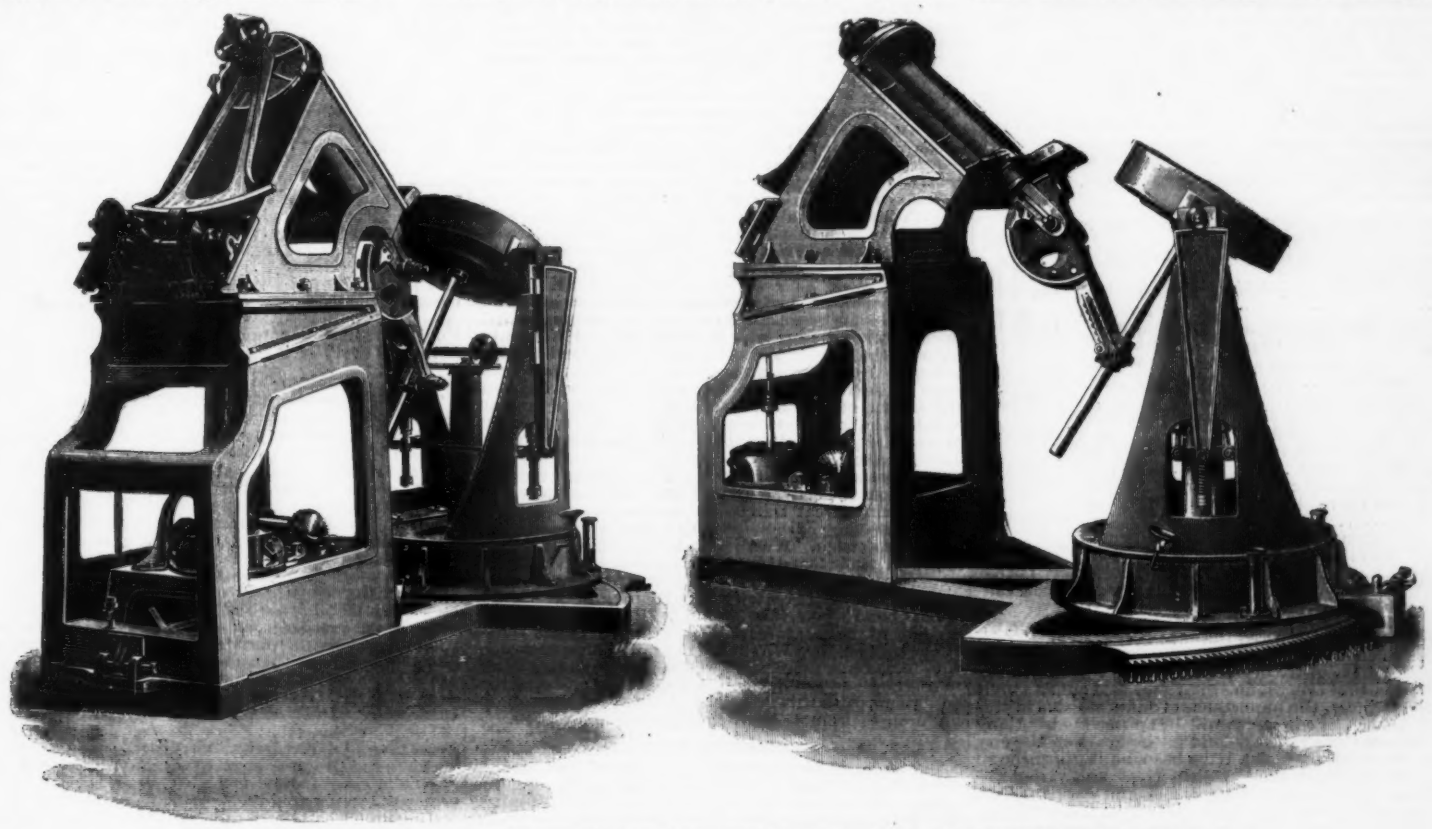
HELIOSTAT FOR THE SMITHSONIAN INSTITUTION, WASHINGTON.*

By Sir HOWARD GRUBB.

IN a large heliostat which I have recently made for the Smithsonian Institution, of Washington, I have introduced some modifications which may possibly be interesting to members of the Royal Dublin Society. Some of them were designed to meet certain peculiar conditions imposed upon me in the contract, and some were introduced in the hope of improving the efficiency of an instrument which, from its necessarily unmechanical construction, is unlikely ever to take rank as an instrument of precision.

The heliostat, or siderostat, as it is sometimes called, is, as its name implies, an instrument carrying a mirror, or mirrors, which reflect the rays from any celestial object in a constant direction, irrespective of the apparent motion of that object due to the diurnal rotation of our earth.

There are many forms given to these instruments according to the various uses to which they are intended to be applied, but all these modifications may be classified into two essentially different forms, viz., the double mirror and the single mirror heliostat.



HELIOSTAT FOR THE SMITHSONIAN INSTITUTION, WASHINGTON, U. S. A.

The double mirror heliostat is a comparatively simple instrument. It consists essentially of an axis carrying a mirror at one end, the axis being mounted precisely parallel to the axis of our earth, similarly to the polar axis of any equatorial instrument.

This mirror is so set as to reflect the light from the object under examination in the direction of the axis itself, *i. e.*, toward the north or south pole. If now in the direction of this axis another mirror be placed capable of being set to any position, the light from the celestial object can be directed into the desired position, in which position it will remain constant so long as the polar axis is kept rotating at the same rate as our earth, and in an opposite direction.

The simplicity of this arrangement is so great that it would no doubt be invariably adopted were it not that the second reflection causes some additional loss of light, which, for some purposes of research, is undesirable.

The single mirror heliostat is a much more complicated instrument. The best known arrangement is that called the Foucault heliostat. There are many modifications to suit particular conditions, notably that of Dr. Stoney's, which has already, I think, been described at this Society, but the same general principle is embodied in all.

The single mirror heliostat consists essentially of two parts. One is a mirror mounted with a vertical and horizontal motion, and capable, therefore, of being placed in any angular position. It is carefully balanced, and attached to its box is a strong cylindrical bar. In Foucault's design this bar projects at right angles to the plane of the mirror; in Dr. Stoney's the bar is in the same plane, or parallel to the plane of the mirror.

The second portion of the instrument is similar to any ordinary equatorial mounting of a telescope. It has its polar axis set parallel to the pole of our earth, and carried by clockwork. On one end of this is mounted a declination axis, which generally carries a small telescope for finding purposes. Across this declination axis is mounted another, which is prolonged into a fork-shaped casting at one end, in which is carried on a pair of trunnions a casting which slides on to the bar above described as attached to the mirror box, and which forms the connection between the two parts of the apparatus.

If the equatorial portion of the instrument be accurately adjusted and placed in position, and the distance between the center of declination axis and the center of motion of mirror be made exactly equal to the distance between the center of declination axis and the centers on which the slipping pieces work in the fork, any object seen in the little finder telescope is reflected from the mirror in a direction which is a prolongation of a line drawn from center of declination axis to center of motion of mirror. If then the polar axis be kept rotating at the proper speed and in the proper direction, the light from that object will be reflected in a constant direction.

To any one who has used a single mirror heliostat or is familiar with its construction it is unnecessary to point out that while in some positions near the meridian, and with moderate altitudes, a fair amount of accuracy of motion can be obtained, in other positions the direction of the driving force acts at such acute angles that the greater portion tends to twist or bend some part of the apparatus, instead of driving it in the required direction, while in some extreme positions the mechanism often refuses altogether to work.

As the geometric principles involved actually necessitate the existence of these very unmechanical conditions, there appears to be no opportunity of improving the construction except by making the instrument in such a manner that the work to be done shall be as light as possible, while the driving portion of the instrument, which is to do the work, is as strong, rigid, and powerful as possible.

In the present instrument therefore (see illustrations above), the mirror is mounted on a pair of trunnions, which bear lightly in Y bearings; but 90 per cent. of the weight is carried on a pair of sectors which are equivalent to friction rollers of 4 ft. diameter. The frame in which these trunnions are carried, which is very massive and heavy, revolves on a strong steel taper spindle, and has a flotation tank attached, which neatly fits into a cast-iron cistern forming the base of that portion of the instrument. Mercury is poured into this, and thus 90 per cent. of the weight of the whole mirror-carrying apparatus is actually floating on mercury; the result being that this frame, mirror, etc., which weighs some 200 lb., can be revolved, etc., by a force of less than 2 oz.

On the other hand, the equatorial portion which acts as the driver is made of a strength and solidity capable of carrying efficiently a 6-in. or 8-in. telescope, and the clockwork is of the same size and strength used with the instruments for the photographic survey, which each carry a 13-in. and 10-in. telescope. In this way I hope to attain an accuracy of movement greater than is obtained with instruments of the usual proportions.

The clockwork is supplied with the newest form of electrical control, which from recent experiments with the photographic telescopes, we find we can thoroughly depend on to the one-fortieth part of a second.

This particular instrument is intended for use with a large spectroscope placed at 50 ft. distance, the slit of which is always in the same position, and of course vertical.

The slow motions in right ascension and declination are available to the observer at this 50 ft. distance by cords, etc.; but, besides, there are other motions necessary.

As the slit is necessarily always vertical, it is sometimes desirable to be able to give a purely vertical or horizontal motion to the image. When the object is exactly on the meridian, the slow motions in right ascension and declination do then give horizontal and vertical motions, but not when in any position off the meridian. It is necessary therefore to have another pair of slow motions which will cause the image to move in a purely vertical and horizontal direction, whether the object be at the meridian or off it.

The vertical slow motion is effected by the simultaneous raising or lowering of the two vertical bars, which carry the bearings of the mirror trunnions. On the upper end, each of these bars has a screw cut upon it; the nuts which fit these screws are cut into teeth, forming miter wheels, and these two miter wheels or nuts are coupled together by a horizontal shaft to which the 50-ft. slow motion rod is geared.

The horizontal motion is effected by a tangent screw and nut which moves the whole mirror frame horizontally about a center, which is vertically under the center of the declination axis. In addition to the small horizontal motion required for this, the whole mirror frame can be rotated about this same center, through 45 deg. on each side of the meridian, so that for certain special purposes the reflected beam of light can be directed to the S. E. or S. W. instead of due S. The vertical and horizontal slow motions mentioned above are connected to shafts 50 ft. long to bring them under the control of the observer.

The adjustments of these instruments are very numerous and delicate. It may be interesting to note how some of these were effected.

A portion of the "bushings" carrying the trunnions of the piece which slides on the bar attached to the mirror was cut away to allow a striding or hanging level to be applied to these trunnions.

* Paper read before the Royal Dublin Society.—*Engineering.*

By a series of testings and reversals, these trunnions were brought exactly at right angles to the shaft which carries the fork on which these trunnions revolve. By a second series the shaft itself was brought at right angles with the declination axis, and by a third series the declination axis was brought at right angles with the polar axis.

The polar axis was then set to the correct inclination by an "inclinometer." Thus the whole equatorial part was adjusted without aid of any celestial observations, in every respect except azimuth, which can only be found by observation. Then a specially prepared plumb bob hung from center of declination axis gave the exact position of the center of rotation of the mirror frame, and finally (the slipping piece having been removed from its fork) the fork was raised until its centers coincided with the horizontal axis of the mirror. Bushings with small electrical holes were fitted into the bearings of mirror and of fork, and a fine silver wire stretched through all four holes; this insured that the distance from declination axis to mirror axis was precisely similar to that from declination axis to center of motion of slipping piece, and this completed the adjustment so far as it is possible to do it mechanically.

SOME ENGINEERING WORKS *

By E. L. Corthell, Member Western Society of Engineers.

Members of the Western Society of Engineers and Guests: It is the custom for retiring presidents to deliver an address upon the engineering progress of the age, or of the ages, to show what advance has been made by our profession in adapting the laws of nature to the wants and convenience of man. It is hoped that a departure from this usual course will not be a disappointment to you. It is proposed to briefly state the conditions in which we are placed as members of this society and the demands upon us for professional work, and then to describe briefly some of the engineering works of the world, not only those that have been completed and are monuments to the genius of those who have conceived and executed them, but of other works now in process of construction, and of still other works that are simply projects as yet, but likely in the near future to be realized in actual construction.

It would be difficult to find any section of our great country where there are greater demands on the civil, mechanical, and electrical engineer than that section of the country of which Chicago is the central point. Perhaps nothing will bring this out more vividly than a summary of a statement recently prepared to show the importance of this city as a transportation center, a place to receive and dispatch goods and to move great masses of people.

Total length of main lines with terminus in Chicago	54,411
Tons of freight received and forwarded during 1889	43,013,444
Number of passengers handled during 1889	18,070,495
" " " " per day	48,965
Suburban passengers handled during 1889	10,759,108
Total length of street car lines in miles	115 2-10
Number of passengers handled by street car lines (1889)	163,000,000
Average per day	446,576
Tons of freight received and forwarded Chicago port (1889)	8,900,000
Tons of freight received and forwarded Ill. & Mich. Canal	790,375
Number of passengers that can be handled by the railroads and street railways per day	3,210,000
Number of passengers that can be handled by the railroads and street railways per hour	170,835

44,951 car loads of freight can be handled daily in Chicago freight yards.

When it is remembered that the vast system of railroads which does the immense business stated in this summary has mostly been built within the last thirty years, and that every mile of it was staked out and built by an engineer, the importance of our profession in this great branch of commerce will be appreciated. Along the lines of these railroads and in the heart of the city itself, to which they lead, have been built up, through the facilities which they furnish, great and varied industries. To this port there comes and goes a freight tonnage as great as any city in the world, not excepting Liverpool. Piers, docks, elevators, harbor works, all are necessitated by this transportation business by rail and lake. The river which meanders through the heart of the city requires bridges and tunnels for crossing it, and that same river (if it be a river) receives the sewage of nearly a million inhabitants, and yet has no natural outfall except into the lake whose waters these inhabitants drink.

This state of affairs in a city growing like ours has led to a development of plans, and nearly to their realization, which will not only, when carried out, remove from us, through the purifying influence of a great body of fresh water flowing toward the Mississippi River, the sewage of the city, but will also furnish an enlarged water transportation between the great lakes and the Gulf of Mexico. Here certainly is a field for the highest class of engineering—here are difficult problems in hydraulics and in construction which are presented for immediate solution.

Let it be also remembered that the metropolitan district of Chicago has not attained its growth. Far from it. That growth is still phenomenal among the cities of the North, it being estimated by statisticians that the rate of growth at the present moment is 900,000 per decade, with an increasing increment. No one can forecast the future or predict the magnitude of the city where we have cast our lot as engineers, nor can any one measure the possibilities which are before us as a society of engineers. Certainly these conditions, so important and so grand in their future results, demand of us not only to give ourselves to the engineering problems as they come rapidly following each other, but that we should organize ourselves as professional engineers into a society, in order that we may be the better able to discuss, to solve and to successfully handle the problems as they are presented.

It is a satisfaction to know from the report of our secretary that the Western Society of Engineers, whose headquarters are in this city, is not in a moribund condition, but in one of active growth, for this report shows that the increase in membership during the last year has been 40 per cent. of the entire membership at the beginning of the year, and it is safe to say that this membership is an active one, that there is no dead wood in it, that the men who have joined this society during the last year have done it with a purpose, and that purpose has been twofold no doubt; first, to promote the general interests of engineering in the city and in the country tributary to it; and, second, to promote their own individual growth and usefulness as engineers. This society has arrived at that point where there should be only active membership and where every one should take hold in earnest to make the society with its meritorious objects an eminent success and of great usefulness in the important section of the country where it is placed.

It is safe to predict that this society will make its mark, and that broad and deep in the progress which this city is bound to make in the future, and it is our duty to prepare ourselves for our work by strengthening our borders, by perfecting our organization in every possible way, and by each one taking up the duty that devolves upon him as a member of the society and faithfully performing it.

The subjects which we discuss should be live subjects, those pertaining to the great engineering wants of our country and of our city. More papers are needed from the membership. All of us have some experience in our work. We have accomplished something, the relation of which will be of interest and profit to the others, and hardly any subject which involves the construction of public works can be described without eliciting discussion, which in itself will be of advantage. A most earnest appeal is therefore made to the society to bring forward for information and for discussion the results of experience, the results of thought and of plans which have been carried out or which exist only in the brain of the engineer.

We wish it also understood, not only among ourselves and with our guests who honor us with their presence to-night, but throughout the city and section of country where our membership reside, that all intelligent men who are interested in engineering and constructive questions and works, and who desire a membership with us, are welcome here. Our meetings for the reading of papers and discussions are also open to all who have a desire to attend. And should our rooms become so contracted by our increased membership and by the growing interest in our discussions that we cannot conveniently take care of those that come, we will have sufficient reason for enlarging our borders.

With these general remarks pertaining to our city, our society, and to our engineering conditions, we desire to interest, and we hope to entertain you as well, by describing and illustrating by lantern views some engineering works selected, some for their novelty, some for their peculiarities of foundations, some for their grandeur, and some because of a personal acquaintance with them, and so better able to describe and illustrate. Some of these descriptions have been obtained directly and quite recently from engineers who built the works, some of them from histories of the works and from engineers and others connected with them, both in this country and in Europe, who also have been kind enough to send the photographs from which the lantern views have been made.

The views of these works as they appear one after another on the canvas, should serve to stimulate us as engineers to great things—to surpass, if we can, the works here shown, some of which are by the masters in our profession. We should be unwilling simply to follow in their footsteps. The increasing demands of commerce should lead us to dare still greater things—to undertake still greater works than those which will appear before you this evening. Practically there is no limit to the greatness and the grandeur of the works of our profession. We should not only imitate the men who have built these great works, but we should study to originate and to develop in order that we may surpass them, with this great object always in view of doing it all to promote the welfare of our fellow men.

LIVERPOOL DOCKS.

The docks of Liverpool on both sides of the Mersey are under the same trust and management. On the Liverpool side they extend along the estuary 6¼ miles. The Birkenhead docks have less frontage but extend a long way backward. The water area of the Liverpool docks and basins is 333¼ acres, with a lineal quayage of 22 miles. The Birkenhead docks contain a water area of 160 acres, with a lineal quayage of 9 miles.

The system of floating docks was commenced by the corporation in 1709. In 1856 the control was taken from the corporation and the management vested in the Mersey Docks and Harbor Board, consisting of twenty-eight members. Since 1880 the annual revenue has been over $6,000,000. In addition to the floating docks, there are in Liverpool eighteen graving docks and two gridirons. In Birkenhead three graving docks. In 1860 the number of vessels entered in Liverpool was 4,746, with a tonnage of 450,060. In 1880 vessels entered 20,249, tonnage 7,933,620. In the number of ships registered as belonging to the port, Liverpool stands first in the world. The size of the ships has greatly increased, having reached 10,000 tons burden, with 20,000 horse power.

MENAI SUSPENSION BRIDGE.

Near Bangor, North Wales, the mainland is separated from Anglesea Island by the Menai Straits. A bridge over these straits was built by Thomas Telford, civil engineer.

Active construction was begun in 1820. On the Bangor side of the strait solid rock was found at a depth of seven feet. There are three arches on the east side and four on the west or Anglesea side. The construction of these arches required four years. The piers were 65′ high from high water line to the springing of the arches, the span of each arch being 52′ 6″. The two principal piers for the suspension of the main chains were 153′ in height.

The central portions of the main chains were built on a raft 450′ long and 6 wide, floated to the bridge site and lifted in place by capstans and tackle. The capstans for hauling in the ropes bearing the main chains were manned by 150 laborers, showing how crude were the appliances with which the engineer was compelled to work even on such a stupendous work as this was for those times. The engineer had no past experience to guide him in designing his iron work. The failure of the bridge was predicted, and it was freely spoken of as "a castle in the air." Total length of the bridge is 1,710′, the distance between points of suspension of the main bridge is 579′, the main chains are 16 in number, deflecting 37′ each, composed of 36 bars of ½″ square iron placed so as to give a square of 6″ on each side. Total weight of iron 2,187 tons in 32,265 separate pieces. The cost, including embankment, half a mile of new road, and toll houses, was $600,000. The bridge was opened for traffic January 30, 1826.

BRITANNIA BRIDGE.

The Britannia Bridge crosses the Straits of Menai. The bridge consists of two independent continuous tubular beams, each one being 1,511 feet long, weighing some 5,242 tons, not including cast iron pedestals. A single track through bridge of two spans 460′ each and two 230′ each weighs 1,800 tons, about one-third of what the single track Britannia bridge weighs.

The bridge is divided into four spans, two of 460′ each and two of 230′ each. The distance between shore lines at high water mark is 1,100 feet. The first stone was laid April 10, 1846, and the bridge was finished March 5, 1850. The substructure consists of two abutments and three piers. The center pier is known as the great Britannia tower. It is 230′ high and is built on a rock in the middle of the Strait. The masonry is massive rather than beautiful. The two side spans over land were built on falsework in exact position; the two middle spans were erected on wooden platforms at high water on shore and floated into position between piers. These spans were placed on rests cut into piers near high water line and then raised by hydraulic jacks into position. The first big tube was floated on pontoons June 19, 1849; the last tube was floated December 3, 1849, and set in its permanent position January 7, 1850. The long spans weigh about 1,718 tons each; the clear width of roadway in tubes is 15 feet; the clear height 23 feet at ends and 30 feet at center of span. The tubes are fixed on the center pier and have roller bearings on other piers and abutments.

Some 1,008 tons of rivets (fully 2,000,000 rivets) were used in the bridge. The total cost of the structure as built is $1,172,250. The structure was built by Robert Stephenson, his father, George Stephenson, being consulting engineer.

The difficulty of raising such immense structures as these to so great a height with such appliances as were available at that time was very great, and in one or two instances accidents happened which threatened to bring destruction upon the work, but it was avoided by the extraordinary precaution and great detailed care which was taken by the engineer in all of the plans and appliances. The history of this work and of this man, of his father and of other great engineers of that time, Telford, Rennie and Brindley, and others, is admirably described in Smiles' Lives of the Engineers, in five volumes, which should be in the library of every civil engineer.

GARABIT BRIDGE.

The engineer was M. Gustav Eiffel. The structure crosses the valley of La Truyere at Garabit, and is composed of a metallic viaduct of 1471′ length abutting on each end against masonry approach viaducts. The rail is at an elevation of about 400′ above the lowest point of the valley. The metallic portion of the viaduct is composed of a straight latticed girder, or system of girders, supported at each end on masonry abutments which form part of the masonry viaduct. The girder is further supported over each slope of the valley by metallic towers resting on blocks of masonry, and over the deepest part of the gulch by bents resting on a large metallic arch of 541′ span.

The lattice girder consists practically of three continuous girders, the portion over the arch comprising one part and from the ends of the arch to the masonry approach viaducts the others. The girders are 17′ deep and the trusses are spaced 16½′ apart between centers.

The floor beams have five lines of stringers resting upon them, on which the corrugated floor is placed. This floor is strong enough to support the weight of an engine in case of derailment. The supports or bents under the spans are hinged, some being fixed and some resting upon cast iron rollers. The hinged supports have the advantage of causing the resultant to pass through the axis of support, which is a condition necessary in the case of very high towers.

The structure was figured for a live load of 3,219 lb. per lineal foot of track. The height of the lowest bent is 199·23′. The batter of the posts in the bents varies, being generally 1″ per foot.

One item not usually found in American structures is a metallic stairway in the center line of the tower running its full height. This is built to facilitate the inspection of the structure.

The wind pressure used in calculating the strains was first a full live load and thirty lb. per square foot; second, no live load and 55 lb. per square foot.

The Central Arch.—The chord of the central arch is 541′ long. The rise of the intrados is 170′ 1¾″. It may be said to be composed of two large bents symmetrical with regard to a vertical plane passing through the center line of the track, but situated in two planes inclined toward each other.

The bents are 65′ 7/16″ apart at the bottom and 20′ 5/16″ at the key measured on the intrados. This arrangement makes the arch very stable against wind pressure. The two inclined bents are in the shape of a crescent, the middle fiber being a parabola. They are very high at the key, but terminate in a point at each base. These points are hinged, thus forcing the resultant pressure to pass constantly through that point. This shape of arch has the advantage of giving it sufficient rigidity to resist the deflection due to uneven distribution of rolling load.

Each bent is composed of a top and bottom chord in the shape of box girders; the bottom one having the cover plate on the lower side. The open sides of these chords are latticed with angles. The vertical and inclined struts joining these chords are built of four

* Address on retiring from presidency of the Western Society of Engineers. Read January 8, 1890. From the *Journal* of the Association of Engineering Societies.

angles latticed. The two bents are tied together by horizontal cross struts. The bracing is completed by a very strong diagonal bracing in the intrados and extrados plane, the members being built of four angles latticed on all sides.

The foundations are on rock almost at the surface of the ground. The estimated cost of the structure is as follows:

For masonry, including the approach viaducts, $142,857.14; for superstructure (the metallic part), $447,619.05. The total cost, $590,476.19.

The price per running foot of the whole viaduct is $324.81; price per running foot of the metallic part, $331.09.

SAULT CANAL.

The Sault canal and locks were built to carry commerce around St. Mary's Falls. The old canal and locks were built from 1853 to 1855. The locks, two in number, are each 70 feet wide, 350 feet long and have 11½ feet of water over miter sills. They have a lift of 9 feet each. Total cost of canal and locks was $999,802.46.

The work of enlarging the canal and rebuilding the locks was commenced in October, 1870, and finished September 1, 1881. The total length of the canal is about 1¼ miles (7,000 feet); the least width, 108 feet; depth, 16 feet. General height of canal pier revetment work is 4 feet above mean water surface. The new lock chamber is 515 feet long, 80 feet wide narrowed to 60 feet at the gates; depth, 39½ feet, with 17 feet of water over miter sills. The capacity is 1,500,000 cubic feet.

The cut stone came from Marblehead, Ohio, and Kelly's Island. Backing stone from Drummond's Island and St. Mary's River. Face stone, miter and breast walls and portions of wall adjacent to springs of water were laid in English Portland cement; the remainder of the work in Louisville cement. 34,207 cubic yards of masonry were used, 35,000 barrels of cement being used in this masonry, every barrel of which was tested before use.

Miter sills are oak timbers 12″x18″ fastened to the bed rock by bolts 10 feet long.

There are four gates, upper and lower lock gates and upper and lower guard gates. Weight of one lift of upper lock gate is 40 tons; the weight of one lift of lower lock gate is 76 tons. Both lifts of the upper guard gate are provided with valves with which to fill the lock after it has been pumped out. The lock can be filled through the above valves in about one hour. The guard gates are only used in case the lock gates are disabled or repairs are being made to the lock. Water is let into the lock from culverts under the floor. Each culvert is 8 feet clear, the water passing into the lock chamber through 58 apertures in the lock floor.

MACHINERY FOR OPERATING GATES AND VALVES.—Power is obtained from two 30-inch turbines geared to a main shaft, water being brought to them through a supply pipe from above the lock.

Two accumulator pumps are used, both of which can be run by one turbine at ¼ gate. The accumulator is loaded so as to give a pressure of about 120 lb. per square inch.

The movable dam is designed to check the flow of water, so that upper guard gates can be closed in case the lock gates are accidentally carried away. The dam consists of an ordinary swing bridge, one end of which can be swung across the canal. A series of wickets is suspended side by side from a horizontal truss beneath the bridge. The total cost of improving the canal and the new locks was $2,150,000.

MANCHESTER SHIP CANAL.

The first consulting engineer was appointed (to look into the project and report) in the summer of 1882. It was only in August, 1885, after making three trials, that the sanction of Parliament was obtained for building the canal. Before a single sod was turned in the great work $1,750,000 was spent in forwarding and contesting the canal project. In July, 1886, the contract for building the entire canal was let to Mr. Thomas Walker for $28,750,000. The allowed time for finishing the work was four years, with a large bonus for whatever time was gained in finishing.

The canal extends from Eatham Locks on the south bank of the estuary of the Mersey River to Manchester, having a total length of a little over 35 miles. The minimum width on the bottom is to be 120 feet. The depth throughout is to be 26 feet. This is a very large cross section when compared with existing canals, which are as follows:

Ghent canal, 55′ 6″ wide on bottom, 21′ 2″ deep.
Suez canal, 72′ wide on bottom, 26′ deep.
Amsterdam, 88′ 7″ wide on bottom, 23′ deep.

Many minor streams are to be siphoned across the canal. The Mersey river has to be crossed six or more times The Bridgewater canal has to be carried across the ship canal by a swing bridge, no water being wasted in swinging. At this point also a hydraulic lift is to be built to lower barges and boats from the Bridgewater canal to the ship canal, thence across it and up on the other side to the former level.

Quite satisfactory progress has been made on the entire work up to a recent date, when Mr. Walker very suddenly died.

Mr. E. Leader Williams is the chief engineer of this work and has been one of its principal promoters from the beginning.

As originally designed the canal was to extend several miles into the Mersey, and it was upon the effect of this extension that Mr. James B. Eads gave an opinion which was conclusive to Parliament that the works built as designed would lead to the deterioration of the channel over the bar at Liverpool. His argument on this subject, with the illustrations drawn from maps and notes, some of which were a century old, is one of the best engineering papers extant, and was so conclusive to the minds of the committee that the plan was thrown out immediately. It was for this, on which he spent about three weeks' time, he received probably the largest professional fee ever received by an American engineer, at least, for an equal time spent on any subject, namely, nearly $17,000.

PANAMA CANAL LOCKS.

They were designed by Mr. Eiffel and were to be eight locks, four on the Atlantic and four on the Pacific side of the isthmus.

Four locks, two of 8 meters (26¼′) and two of 11 meters (36·9′) lift, will reach an elevation of 38 meters (124·67′) from Colon on the Atlantic side. Four other locks, three of 11 meters (36·09′) and one of 8 meters (26 1-7′), will reach an altitude of 41 meters (134½′) measured from the Pacific ocean at Panama. The Eiffel locks 18x180 meters (59′x590½′) are about as follows:

The gate is really a large caisson which rolls in and out on tracks on a swing bridge, much like a big barn door hung on rollers and tracking overhead and underneath. The lower part of gate is arranged somewhat like the working of pneumatic caisson. The caisson is suspended on rods fixed to wheeled trucks rolling on tracks as noted above.

The general dimensions of a lock of 11 meters are as follows:

Down stream gate, height 21 meters (69·88′), width 4 meters (13·12′), length 21·6 meters (70·85′). Up stream gate, height 10 meters (32·8′), width 3 meters (9 84′), length 21·6 meters (70·85′). For an eight meter lock the height alone varies, other dimensions remaining about the same.

The free section of the canal left by the opening of a gate is 18·6 meters (61′) at bottom and 20·6 meters (67½′) at the top or surface level. The locks are so located that they will be excavated in solid rock with very light masonry supports where the rock is shattered. The side walls are made of iron caissons having cast iron bracing, the interior being filled with beton. The dimensions of these side caissons vary with the size of the locks. For a lock of 11 meters lift they would be 5½ meters (18′); 24·25 meters (79½′) in height, 30 meters (98·4′) in length.

The caisson gates and swing bridges will be operated by chains running over guide rollers and worked by hydraulic power derived from turbine water wheels. The lock holds about 14,120,000 cubic feet of water, and it is intended to fill it in fifteen minutes. Two cast iron mains about 9′ in diameter are to be laid under the entire length of the lock. They will be pierced at intervals of about 6½′ by holes 1·3′ in diameter. These pipes are deflected toward the side walls of lock entrance. Inside these walls they ascend to a height of 32 feet above the platform level, where they terminate in a sluiceway for valves opening into the canal. The estimated quantity of wrought iron needed in these gates will be 15 tons, and cast iron 20,000 tons.

Mr. Eiffel designed and, it is believed, took a contract for the construction of these locks and their gates. It may be of little interest at this juncture of Panama canal affairs to describe these locks, but it is given for the purpose of showing the ingenuity and extent of the locks and of the works connected with them The contemplation of this whole subject of the Panama canal brings anything but pleasure, but it is a satisfaction (though a poor one) to state that very few American engineers who had given the subject close attention believed that the original sea level canal, on which several hundred million dollars were spent, was practicable, and it is to their credit that they publicly protested against such a wasteful expenditure of money, when there could possibly be nothing but failure in the result. It is extremely doubtful if the lock plan is feasible in operation, at least, on acount of scarcity of water at times, and it is doubtful whether the works will be carried forward any further. The entire enterprise is in the hands of a liquidator appointed by the French government, who has sent a commission of French engineers to Panama, who are due there about this time, and whose duty it will be to make a general survey of the isthmus, the condition of affairs and the state of the work, and report to Mr. Brunet, the liquidator, what in their opinion is the best method (if any there be which can be successful) of completing the work and opening it to commerce. It has been asserted by those who are competent judges that the only successful method of overcoming this great barrier to commerce at the Isthmus of Panama is by a ship railway connecting the dredgible portions on each side.

ST. LOUIS BRIDGE—JAS. B. EADS, ENGINEER.

The first work on the bridge was in August, 1867. The bridge was formally opened in July, 1874. The river at the bridge site is narrowed to about 1,600′ in width at low and ordinary stages of water by a dike built along the Illinois shore. At high water the width is about 2,200′. The bottom is changeable, being covered with a heavy bed of sand and gravel (the sand being very light), which is liable to wash out almost if not quite to bed rock during any heavy freshet, records having shown that 50 ft. or more in depth have been cut out during one freshet.

The bridge has three spans formed of rolled steel ribbed arches, each span being made up of four double ribs of steel so cut as to form one heavy arch. The spans are 503′, 520′, and 503′ in the clear between the piers. The rise of the center arch is 47½′, and of side arches 46′. The total length between abutments is 1,627′. The clear headroom above the water center of the arch is about 53′. The range of the river between high and low water is a little over 41′.

The piers are founded on bed rock, the final locations below low water being as follows: East abutment 94′, east pier 85′, west pier 56′ 10″, west abutment 13′. At the time this bridge was built engineers did not understand how to protect workmen from bad effects of compressed air as well as they do now, and in sinking the piers 600 men were attacked by sickness; 14 deaths occurred and two victims were crippled out of the 600. The maximum air pressure was about 50 pounds above the normal. The greatest depth at which pressure was carried was about 110 feet.

The superstructure was erected without falseworks. Temporary towers some 50′ high were raised on the tops of the piers and cables run from these to the semi-arches. On the piers the work was built out from both sides at the same time, keeping the parts balanced, while at the abutments the switch cables were run over towers and anchored securely on the shore. The maximum strain in these main cables was 170 tons.

The size of the piers is as follows: East abutment at base 83x70½′, at top 64′ 3½″x47′ 6″. The east pier 82′x 60′ at base and 63′x24′ at top. The west pier 82′x48′ at base and 63′x24′ at top. In these main piers and abutments some 68,727 cubic yards of masonry were used in all, being faced with granite. The total weight of metal in the three main spans was some 5,547 tons, the weight of railway track, etc., was estimated at 215 tons, the estimated weight of lumber in the bridge 806 tons, the total weight of the three spans 6,568 tons, or 4·3 tons per foot. The total cost of the bridge was $6,536,729.99. This was somewhat in excess of the engineer's estimate, due to two causes; first, enlargement of plans made during construction; and, second, unexpected difficulties in sinking the piers. This was largely due to its being in nearly every respect a pioneer work. No such depth had ever before been attempted; the length of spans were unusual and the character of the spans were equally unusual. The bridge has not only two tracks for railroads, but above them a wagon bridge about 50 feet wide This added largely to the cost of the approaches on each side of the river. It is considered rightfully one of the most beautiful engineering structures in the world.

THE NEW YORK AND BROOKLYN BRIDGE.

The engineers were John A. Roebling and his son Washington Roebling.

This bridge was formally opened in 1884 The first actual work on the structure was done in October, 1869. About five years were consumed in building the piers and towers.

The length of the bridge, including anchorages, is 3,700′. The height of the anchorages 85′; the weight of each anchorage is 60,000 tons; the length of each land span is 930′, the length of the middle span 1,600′, the size of the towers at high water mark is 140 × 59′, the height of the towers from high water mark is 272′, the height of towers from the deepest foundation to the top is 350′, the width of grade is 85′. Head room above high water 135′, number of cables four, the length of one cable 3,580′, the finished diameter of cable 15½″, the number of railroad tracks two, the grade of the bridge 3¼ per cent., allowable speed for trains is 10 miles per hour, total cost from anchorage to anchorage, exclusive of land damages, $5,600,000.

The distance from the center of the Brooklyn tower to the face of anchorage is 930′. The anchorage pier on the Brooklyn side is 132′ long by 119′ 4″ extreme width, 85′ 6″ back of face and 109′ 4″ from thence to the end. This anchorage pier is founded on a timber platform some 3′ thick and thoroughly bolted together. All air spaces in the platform are filled with concrete; it is also surrounded by concrete. The anchorages contain about 28,800 cubic yards of masonry for the New York side and 27,113 cubic yards for the Brooklyn side.

BROOKLYN TOWER.—The bottom of the foundation is at a depth of 44′ 6″ below mean high tide. The bottom of the masonry is at a depth of 20′ below mean high tide. Depth of water along the front of the tower from 12′ to 16′. The height of roadway above high tide is 198′.

NEW YORK TOWER.—The bottom of foundation is 78′ below mean high tide. The bottom of masonry is at a depth of 46′ 6″ below mean high tide. The depth of water in front of the tower is 34 ft.

The areas at bottom of caissons are: Brooklyn tower 182′ × 160′ equals 17,136 sq. ft. New York tower 102′ × 172′ equals 17,544 sq. ft.

The area at the bottom of masonry is, for Brooklyn tower 151′ × 49′ equals 8,542 sq. ft. New York 77′ × 157′ equals 1,115 sq. ft.

The Brooklyn tower has 25,394 cubic yards of masonry below the roadway and 6,033 cubic yards from the roadway to the springing line of arches, and 6,787 cubic yards in the remainder of the tower. In the tower and caissons there are about 38,314 cubic yards of masonry, 56,669 yards of concrete and 5,253 yards of timber and iron.

The New York tower has 46,945 cubic yards of masonry, while timber and concrete are about one-third more than in Brooklyn tower. The total weight of the Brooklyn tower is 93,100 tons; the pressure at bottom of the foundation is 5½ tons per sq. ft.; at base of central shaft above roadway about 26 tons per sq. ft. The arches over roadway are 33′ 9″ span and their points 114½′ above the roadbed. The beds of all stone were rough-axed, so as to allow the use of ½″ bed joints. The excavation in the caissons cost for labor alone about $5.25 per cubic yard, and this, with air compressors, lights and other expenses made the total cost, not including any material, about $10.50 per cubic yard. The foundations for the arches were carried down to a solid bottom. In general this bottom was found at a little over three feet above high tide, though in many places they dug from 10′ to 12′ below tide level. The maximum pressure on the bottom under these foundations is about 5 tons per sq. ft.

SIOUX CITY BRIDGE.

This bridge was built over the Missouri River at Sioux City, Iowa, in 1887 and 1888. It is owned by the Chicago & North western Ry. Co. The chief engineers of the work were Messrs. Morison & Corthell, members of the Society, and Mr. E. Gerber was resident engineer.

The bridge consists of four 400′ spans and one 61⅓′ approach girder, all resting on first class masonry supports. The main piers were built on pneumatic caissons which rest on the sandy alluvium of the Missouri River, no rock being found at a convenient depth. The pressure on the foundation material is about three tons per square foot, with, of course, a large frictional resistance on the sides of the caissons and cribs. All of the foundations are about 86′ below low water, the deepest pneumatic work was done at 94′ below low water. The range of the river between high and low water is about 17′, the superstructure for the main bridge weighs 4,485,800 lb.; one 400′ span weighs 1,114,300 lb. There are in the piers and abutments 6,990 cubic yards of masonry, and 3,000 yards of it being granite. It is a single track structure built entirely of steel except a few castings. The views which illustrate this bridge construction are selected from a large number which were taken during the progress of the work, and are intended to illustrate the method and progress of the work from the time when the work was commenced until it was entirely completed and tested. The views will show the methods of building the caissons, of excavating the material, the building of masonry, and the erecting of the superstructure. Many of these stages of the work shown progressively, and as an object lesson, will be of interest to all.

The Union Bridge Company, of New York, manufactured the superstructure.

CAIRO BRIDGE.

This bridge has been recently built by the Illinois Central Railroad Company, and is now open for traffic,

It spans the Ohio River at the city of Cairo, Ill. It is one of the longest structures in the world. It lacks but about 160′ of being the longest, that being the new Tay Bridge. On account of the low banks on either side of the river at Cairo, the great rise of the water, being 52·17′ between low and high water, and the height required for steamboats, 53′, the structure is elevated above the country on each side, so that the entire length of the permanent structure is 10,560′, being made up of the following spans:

Two 518½′ spans,
Seven 400′ spans,
Three 249′ spans,
Thirty-eight 150′ spans,
Two 106¼′ spans.

Total amount of steel in the main bridge was 13,411,656 pounds; in the Kentucky approach there are 4,355,149 pounds; in the Illinois approach 3,496,278 pounds. There are 32,266 cubic yards of masonry in the piers. There are 17 cylinder piers in the Illinois approach and 21 in the Kentucky approach. One 518½′ span was erected in 44 working hours, and one 400′ span in 23 hours. This is believed to be as rapid work as has ever been done in the erection of large spans.

The foundations of the piers were generally placed 75′ below low water, and rested in the alluvial formation of the Ohio River, being in many cases nearly pure sand, in others sand and gravel. Some sand rock and some clay were encountered in sinking the foundations. The entire work in the river was done by sinking pneumatic caissons. The chief engineers were Messrs. Morison & Corthell, the resident engineer Mr. Alfred Noble. The Union Bridge Company, of New York, had the entire contract for the foundations, piers and superstructure of the main bridge and permanent approaches.

OHIO RIVER BRIDGE.

The bridge consists of two spans 490′, one single span 550′ and about 1,500 lineal feet of approach in Covington and 3,000 lineal feet in Cincinnati. The 490′ spans are 484′ 6″ between centers of end pins. The 550′ span is 542′ 6″ between centers of the end pins. The trusses of the main span are of steel, the remaining material of iron. The long span is 84′ deep at center and 60′ at end by 30′ in width center to center of trusses, and weighs 4,000,000 lb. The two side spans are 75′ center depth and 50′ end depth; 30′ in width center of trusses and weigh 3,330,000 lb. each. The structure carries a double track railway and two roadways and sidewalks, and the entire weight is about 24,000,000 lb.

The erection of the iron work of the river spans was commenced July 6, 1888, and though all the false work, the traveler and most of the floor of the long span were washed out by the flood of August 26, and much delay was caused in getting false work in for the Cincinnati shore span, yet the first train crossed the structure December 25, 1888. The last span was swung in sixteen days from the placing of the first iron. In this erection single pieces weighing 37,000 lb. were handled.

The Phœnixville Bridge Co. built this structure. The largest span of this bridge is probably the heaviest independent truss span in the world.

(To be continued.)

THE LARGE SAIL VESSELS OF FRANCE.

DESPITE the rapid diminution in the tonnage of our sail marine, sail vessels will continue, for a long time to come, to struggle against the monopoly of ocean carriage by steamships.

The new iron and steel ships are attaining huge proportions, and, owing to the incessant improvements in naval construction, are now, more than ever before, able to keep up the contest with advantage (chiefly in long trips) against freight steamers or cargo boats.

In France, we have but one large house for fitting out sail vessels, and that is the house of A. D. Bordes & Son, of Paris and Bordeaux, which owns the largest fleet of them extant, and to this, in a few months, will be added the largest sailing vessel in the world. In fact, exclusive of the tonnage of this last ship, which is constructing at Glasgow, the Bordes fleet includes 33 sail vessels of a total net gauge of more than 43,000 tons, and of 70,000 tons burden. Of these 33 vessels, 3 are of wood, 26 of iron, and 4 of steel. Of this number, 7 have four masts, 4 of them being square rigged and 3 bark rigged. Before speaking of the last three, which are of steel, we shall speak of the first four four-masters, which are: The Union, built at Greenock in 1882, of a net gauge of 2,120 tons, and a burden of 3,355 tons; the A. D. Bordes, built at Glasgow in 1881, of a net gauge of 2,231 tons, and of 3,600 tons burden; the Tarapaca, built at Glasgow in 1886, of a net gauge of 2,497 tons, and a burden of 4,140 tons; the Perseverance, built at Glasgow in 1886, of a net gauge of 2,511 tons, and a burden of 4,140 tons.

The Union was a remarkable ship for her time. She is 308 feet in length, 40 feet in breadth and 23 feet in depth. Her four lower masts and fifteen of her yards are of steel, and her double bottom, divided into three tight compartments, is capable of holding about 500 tons of water.

The Perseverance and the Tarapaca have each a double bottom of 600 tons capacity.

This first installation for a ballast of water constituted a great improvement in sail vessels, but it has since been rendered more complete, as we shall explain further along. In fact, a sailing vessel, whose stay in port is necessarily longer than that of steamers, is almost always obliged to take in ballast in order to be kept upright while awaiting her cargo, and this constitutes a pretty heavy load for the equipment. It also causes a very sensible loss of time. Now, this installation of the double bottom for a ballast of water is intended to remedy just this state of things. However, these five or six hundred tons of water, which were sufficient to keep the vessel upright in port, were not enough to permit her to navigate, even under reduced sail. It consequently became necessary to take several hundred tons more ballast on board every time that the

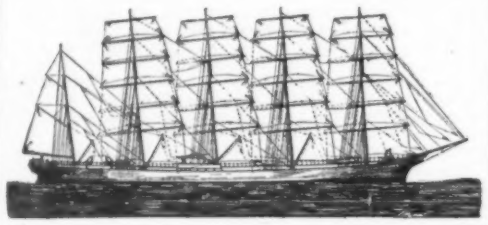


FIG. 2.—THE FIVE-MASTED BARK FRANCE.

ship had to depend upon ballast from her port of discharge to the port at which she was to take on a cargo. Hence a loss of time and new expense for the equipment. Now, the Messrs. Bordes have succeeded in remedying this inconvenience, and their initiative, in this case, is so much the more remarkable in that no English, German or other ship owners have as yet dared to imitate them. But the success they have obtained with their latest ships will have the inevitable result of leading foreign ship owners to follow their example and to install upon their sail vessels tight holds like those that exist on the last three vessels built by the Bordes. This installation of a tight hold in the center is not new, but it has been used only upon a few steamers, and no one had thought of applying it to sailing vessels.

These holds serve for the carriage of merchandise in ordinary times, and are filled with water only when the ship has to sail from one port to another under ballast. Thus the four-master Cape Horn, which left Cardiff with a cargo of coal for Rio de Janeiro, under the command of Captain Voisin, sailed from the latter port for Valparaiso without any other ballast aboard than the water contained in her double bottom and tight hold. This ship behaved perfectly during the trip, and doubled Cape Horn under better conditions than if she had had ordinary ballast in her hold. She even gained several days, for while other ships had waited as long as fifteen days to procure ballast in the roadstead of Rio de Janeiro, she had merely to have her compartments filled and to set sail immediately after the discharge of her 4,500 tons of coal.

The reason that we dwell upon the advantages to sailing vessels of being able to navigate hereafter with water ballast is that this is to permit them to compete more advantageously than in the past with the great freight steamers—their most formidable competitors. The four-master Cape Horn was the first steel ship built for the Bordes, while, at the same time, the first bark-rigged four-master and the first to be provided with a water tight hold. The suppression of yards from the mizzen mast facilitates the maneuvering of these big ships, by diminishing the number of square

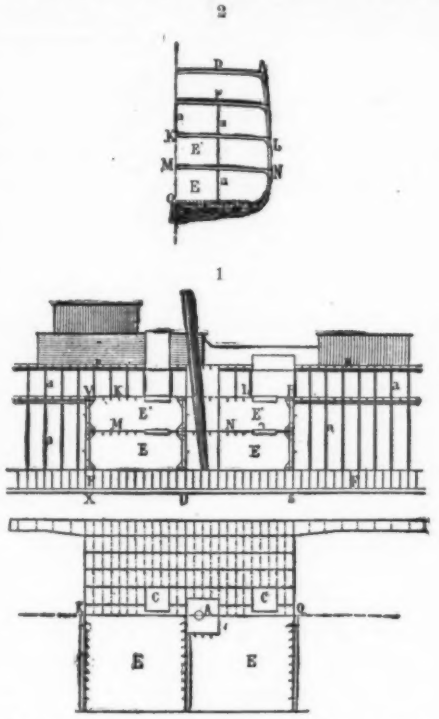


FIG. 3.—ARRANGEMENT OF THE TIGHT HOLD OF THE FRANCE.

1. Longitudinal section. 2. Plan of the central part of the ship. K L, iron deck; R S, V X, transverse partitions; M F, horizontal partitions; F F, double bottom; E E, lower part of the tight hold; E′ E′, upper part of the same; *a a*, stanchions.

sails, and offers, for four masters, the same practical advantages as the suit of sails for bark-rigged three masters, as compared with that of the square-rigged three masters.

The chief characteristics of the Cape Horn are as follows: Total length, 310 feet; breadth, 45 feet; depth, 31 feet; gauge, 2,657 tons; capacity of the double bottom, 28,200 cubic feet; capacity of the tight hold, 1,100 tons; length of the tight hold, 55 feet; height of the two mainmasts, 150 feet; and surface of sails, about 32,250 square feet. There are two boilers for the operating of the auxiliary machines—windlasses, pumps, and capstan. As this ship is of the same type as the Dunkerque and the Nord, which were launched in 1889, a portion of the following details, which relate to the latter, will complete her description.

The bark-rigged Nord was launched at Glasgow on the seventh of December. Her length is 333 feet; breadth, 46 feet; depth beneath upper deck, 25½ feet; capacity of double bottom, 800 tons; capacity of tight hold, 1,100 tons; net gauge, 3,000 tons; guaranteed burden, 5,000 tons. The lower masts and the top masts form but one, as do the mizzen mast and the bowsprit. The masts and yards are of steel, and the plates employed have a minimum thickness of a quarter of an inch. The tight hold is divided into eight compartments, and rises from the double bottom to the lower deck. The steering machine is a double screw apparatus, actuated by two hand wheels. A friction brake placed within reach of the helmsman's foot permits of keeping the rudder immovable as long as necessary. Each of the two water tanks has a capacity of 18¼ tons. There are two tubular steel boilers capable of furnishing the steam necessary for the four steam windlasses operating at the same time. The steam pipes that run from the boiler to the windlasses and capstan are of copper jacketed with felt and painted canvas, and protected by a covering of galvanized iron.

As the auxiliary machines are used in port only, there are, for maneuvering the yards and sails, five double power capstans distributed upon the deck and poop, as well as a strong capstan upon the forecastle. This latter can be actuated by the steam capstan for mooring maneuvers in port. The equipment includes six rowboats. The poop is 39 feet and the forecastle 36 feet in length. A copper tube serves as a speaking tube between the forecastle and poop. The chart room is upon the poop.

As for the new vessel which is now building at Glasgow, for the same house, and which will be the first five-masted bark hitherto constructed, and, at the same time, the largest sail vessel in the world, she will be named the France, and will be launched in a few months. This magnificent steel ship will be 375 feet in length, 49 feet in breadth, and 33¾ in depth, measured from the upper deck to the bottom of the hold. Her net gauge will be 3,600 tons, and her burden 6,100 tons. The principal dimensions of this large ship are as follows:

Bowsprit, 50 feet in length and 12 and 30 inches in diameter; mizzen mast, in a single piece, 140 feet in length; main boom of the mizzen mast, 46 feet in length; upper throat 21 feet; lower throat 43 feet. The lower and top masts are in a single piece, and of the following dimensions, above deck: foremast, 159 feet; fore mainmast, 166 feet; after mainmast, 167 feet.

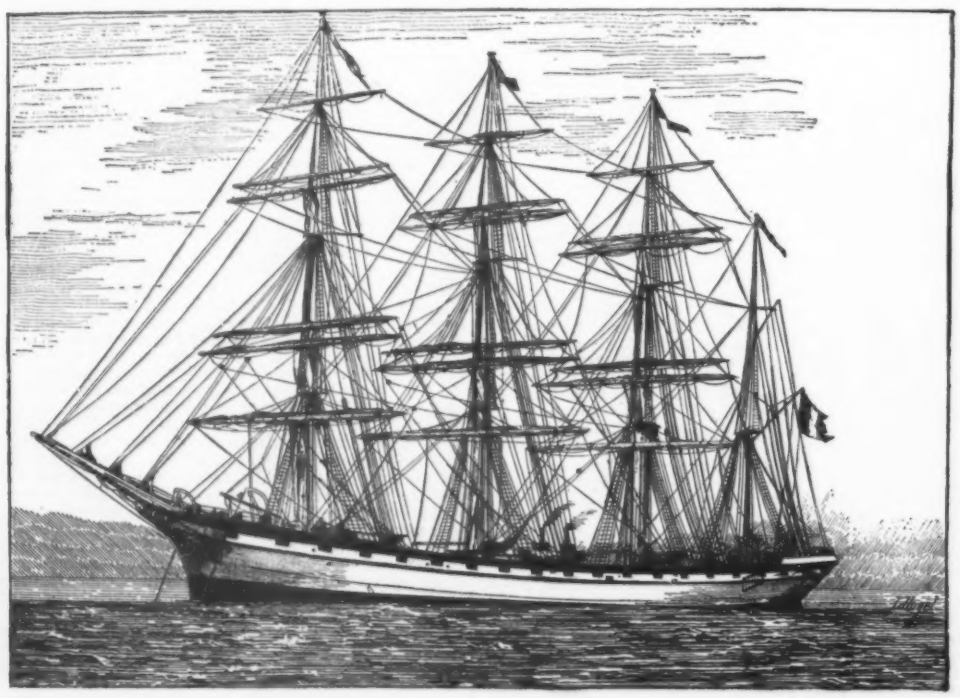


FIG. 1.—ONE OF THE NEW FOUR-MASTED BARKS OF THE HOUSE OF A. D. BORDES & SON.

This height of masts is far from equaling that of our old three masters, which sometimes exceeded 210 feet, but it must be remarked that these new steel ships are shaped like steamers, since they are about seven times as long as broad, and for what they lose in height they make up in the greater number and spread of sails.

The diameter of the masts varies from 30 to 17 in.; that of the top gallant masts is from 16 to 10 inches. The length of the lower yards is 82 feet, that of the upper yards from 75 to 77 feet, according to the masts; that of the top gallant yards is from 59 to 64 feet, and that of the royal yards is 47 feet. The masts are spread about 68 feet apart.

The plan of the sails in Fig. 2 gives a sufficient idea of the general arrangement, and shows the enormous spread of the 24 sails of this huge vessel.

Like the Cape Horn, Dunkerque and Nord, the France will have a double cellular bottom for water ballast, and in the center a tight hold that will contain 1,200 tons of water. As for the double bottom, that will contain about 750 tons of water.

The transverse and longitudinal sections and the plan view of the horizontal partition, M N, of the tight hold (Fig. 3) will show the arrangement of this part of the ship, which is divided into eight compartments, not including the well into which the base of the large mainmast passes. The central bulkhead is placed at a distance of 29 feet from the front bulkhead and 25 from the rear one. The other arrangements of the tight hold and double bottom will easily be understood from what is shown.

The principal dimensions of the tight hold are as follows:

Height under beams of upper spar deck	6½ ft.
" " " " lower "	7½ "
" from one tight deck to the other (upper part)	8 "
" from one tight deck to the other (lower part)	10 "
" from double bottom along the carline	4¼ "
Capacity of each of the upper compartments of the rear	4,760 cub. ft.
Capacity of each of the lower compartments of the rear	5,490 "
Capacity of each of the two upper compartments of the front	5,145 "
Capacity of each of the two lower compartments of the front	5,915 "
Capacity of the eight compartments of the tight hold	42,630 "

We may add that all the ships that we have just mentioned have been built under the special supervision of the Bureau Veritas, the well known international register of classification, the founding of which dates back to the year 1828.

Although most of the Bordes ships were built in Scotland, there are eight that came from French dockyards, and, among others, the Metana, of 1,450 tons burden, built at Saint Nazaire in 1867, and the Bernardino Bravo, of 1,515 tons burden, built at Bordeaux in 1874.

The other sail vessels of this house whose net gauge exceeds 1,100 tons are:

Three masters.	Net gauge.	Burden.	Date.
The Adolphe, iron bark	1,169	1,975	built in 1869
The Victoria, " "	1,197	2,020	" 1879
The Valparaiso, square rigged	1,239	2,000	" 1874
The Chili, bark	1,278	2,020	" 1885
The Pacific, bark	1,473	2,070	" 1867

From the preceding data, it results that the largest ship of this house, in 1881, was of 2,020 tons burden, while the one that is soon to be launched will be of 6,100 tons burden, that is to say, that the burden of sail vessels will have tripled in less than ten years. These extraordinary results are due to the great progress made in recent years by the ship building and metallurgical industries, as well as to the intelligent initiative of a few great ship owners, at whose head stand Messrs. A. D. Bordes & Son, who will soon have the honor of owning the largest sail vessel in the world.—*Le Genie Civil.*

A WATER VELOCIPEDE.

MR. SEGUY has recently patented a velocipede, which, as shown in the accompanying engraving, seems to run upon the water, the supporting apparatus and the motor being entirely submerged. This result is obtained by two iron plate spindles cross tied here and there and properly ballasted, either with pigs

WATER VELOCIPEDE.

of lead or simply with water, so that when the velocipedist is seated upon the apparatus, the wheels are flush with the surface of the water. The motor is a screw actuated by two bevel wheels that recieve their motion from a chain, as in an ordinary bicycle. The rudder is connected with the steering handles of the velocipede through two long horizontal rods and a vertical frame, so that a change of direction is obtained by a simple motion of the handles. As may be seen, this apparatus is not very complicated and will prove a subject of astonishment to many persons, and, from this point of view, a great success as a curiosity may be promised it.

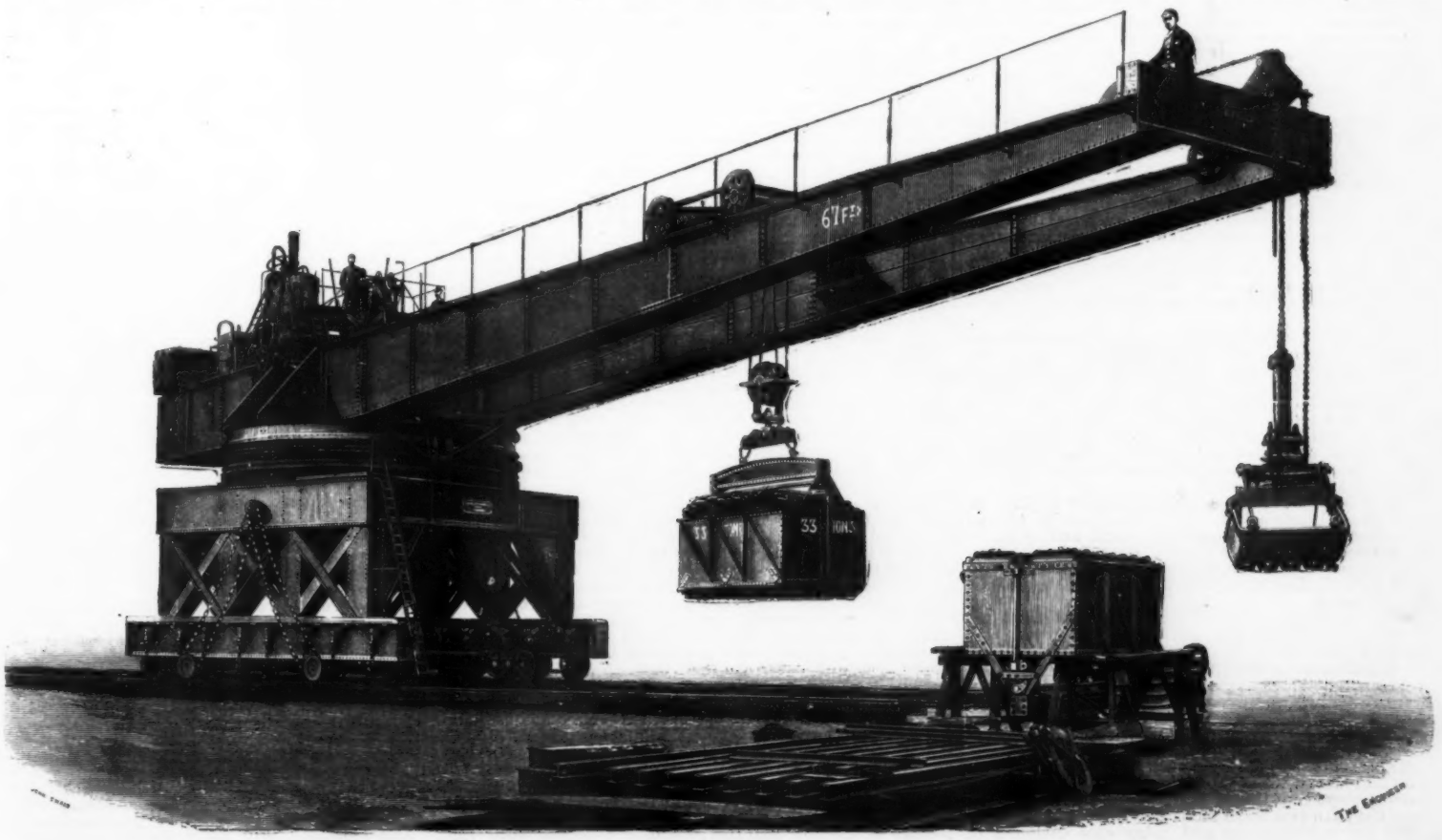
The figure represents a bicycle, but Mr. Seguy proposes to construct tricycles also.—*Les Inventions Nouvelles.*

AN ALL-ROUND TITAN.

WE give an engraving of a remarkably fine specimen of lifting machinery, for which we are indebted to the *Engineer*. It is a large all-round titan built for Messrs. McKenzie & Dobson, the contractors for the construction of the Warrnambool breakwater, for the Victorian government, for which Sir John Coode is the consulting engineer. In designing cranes of this enormous size, one of the greatest difficulties is to secure handiness. Our illustration does not give details, but it shows the general character or type of machinery which has been adopted. The crane has, we are informed, been working in a most satisfactory manner since 1888; the contractors from time to time referring with marked pleasure to its extreme handiness. As compared with other cranes, this is mainly due to the fact that the crane is never blocked up, as has usually been the case with large machines of this kind. The crane does its work upon its wheels, which, being arranged with springs, accommodate themselves in the most perfect manner to the variations in load under various circumstances. It is probably the first instance of a crane of this size arranged with springs capable of dealing with the maximum load without any blocking up. This is, of course, a great advantage, as the crane can perform simultaneously the following motions, or any one of them, without a moment's delay: (1) Traveling; (2) turning; (3) racking in or out; (4) lifting or lowering. The end of the horizontal girders is arranged with one of Cole's single chain grabs, provided for the purpose of preparing the bottom for the reception of the concrete blocks which are lowered in the box shown suspended.

The crane is arranged to run on 21 ft. gauge, and is high enough to let railway trains or the wagons carrying the concrete blocks pass under, but we believe the contractors seldom use this facility, as the crane turns with such ease that they store blocks behind the crane and pick them up as required. The top part of the crane turns on thirty-two conical rollers, the turning rack being on the outer side of the lower roller path. Both the lifting and traversing are worked by means of specially flexible steel wire ropes, made by Messrs. T. & W. Smith, of Newcastle; steel wire rope, being far preferable to chain, appears to be now generally adopted in the best practice. The second motion shaft of the crane gear is provided with a friction brake, and also one of Matthew's patent hydraulic brakes, with which the speed of lowering the blocks can be adjusted to the greatest nicety. From the following figures some notion of the titanic character of the crane can be gathered. The test load was 33 tons at a radius of 67 ft., and the grab is worked at a radius of over 80 ft. The weight of the crane in working order is 320 tons. The gauge of the supporting wheels is 21 ft., and it is mounted on sixteen wheels and thirty-two springs, the average load on each being ten tons, but the front springs carry from eight to twelve tons. Eight of the wheels are traversed by gear, or, in locomotive language, there are eight driving wheels. The turned roller path is 23 ft. diameter, and thirty-two turned conical rollers, 18 in. diameter, run upon it. The wheel base is 25 ft. When the crane is turned round, so as to take its blocks from behind, it can place them 150 ft. from the starting point. Not only so, but the crane can also travel with its full load suspended at the same time that it is turning round, and thus a block can be moved a distance of 200 ft. to 240 ft. in two minutes. The springs referred to have a further advantage in greatly easing the stresses which come on the various parts of the structure when lifting the load. After the tackle is wound taut, the load is brought gradually on to the jib, because, as the load comes on, the jib goes down, owing to the yielding of the front springs, due to the increasing load. In this way the jib goes down nearly a foot under a full load, but its deflection as a girder at the extreme end is only an inch and a half. From the engraving it will be seen that loads can be raised or deposited many feet beyond the test radius. The traveling gear and also the turning gear have spring drivers inserted in their trains of wheels, so as to relieve the cog wheels from any sudden strains.

The turning gear is actuated by double cones, which can be controlled by the finger and thumb with such nicety that the jib can be adjusted to an inch for lateral movement, and for longitudinal movement the crab can be moved in or out with the same facility. The whole duty is performed by the superstructure or moving part of the crane, without calling on the carriage



ALL-ROUND TITAN CRANE—WARRNAMBOOL HARBOR WORKS.

at all. But the moving part has powerful wrought iron claws which would take hold of the flange of the roller path which is fixed on the carriage if any sudden jerk came on the crane, and thus the whole weight of the carriage forms a reserve of stability. All the plates and bars are of mild steel. The crane was built by Messrs. Ransome & Rapier, Ipswich.

SIBLEY COLLEGE LECTURES.—1889-90.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

IV.—CAR WHEELS.

By ROBERT W. HUNT, of Chicago.

IN claiming your attention this afternoon while I endeavor to tell you something about car wheels and their manufacture, I do not suppose I will be able to startle you with the announcement of any new or wonderful inventions, but will endeavor to lay before you a brief *resume* of the present "condition of the art" in this country.

Most likely you are aware that America is the cast iron country, and in no direction is this more pronounced than the general use of cast iron car wheels.

In the earlier days of American engineering, pig metal, in the smelting of which charcoal had been the fuel employed, was the standard. Owing to the then seemingly exhaustless forests, and the undeveloped mines of mineral fuel, no other kind of pig metal received serious engineering consideration. This iron possessed great strength, and no doubt its physical characteristics led our engineers to place more reliance upon cast iron than was the practice of their European brothers.

It is a never failing truth that the demand creates the supply; hence, in the past, American pig iron makers have been able to produce metal equal to the requirements of the then current specifications. At all events, we have successfully used cast iron in many branches of engineering constructions where other nations would not have ventured on its employment.

You may recall that our cast iron ordnance was at one time the marvel of the world. In fact, so long as unrifled cannon could control, we literally "held the fort."

While other forms of iron have conquered in many fields, the cast iron car wheel has not only persistently, but aggressively, maintained its supremacy.

As you may infer from the foregoing, the practice of European railroads is very different from that of this country. John Fernie, a member of the Institute of Civil Engineers, England, said:

"The American engineer set himself to improve the manufacture of railway wheels in the simplest of all ways, by casting them; he improved the manufacture of his pig iron by carefully selecting pure ores and smelting them with charcoal. Then by admixture of various brands he made a metal which would take a deep chill. Then followed improvements by annealing them, and in the cheapest, simplest, and most scientific way produced a wheel center and a tire in one solid piece, unbreakable, and with great endurance, and with the advantage that when worn out on the tread it could, with a small addition of new metal, be cast again into a new wheel. Such are the wheels running under wagons, carriages (the English names for freight and passenger cars) and the heads of locomotives to-day, and for many years they were running as the drivers in passenger and goods engines; of later years these driving wheels have had steel tires shrunk on them. Such wheel centers require no compressive force to hold them together; and no bolts or complicated fastenings of any kind to bind the tire to the center are used in America; and although the temperature varies from 40 degrees below zero to 110 degrees above it, the American wheel is perfectly safe in atmospheric changes which would ruin an English wheel."

Naturally the earlier railway cars were constructed as closely as possible to the designs of road wagons, and this governed as to their wheels. This copying, together with the weakness of the available cast iron, led foreign engineers to adhere to a built-up spoke wheel of wrought material; and this pratice still prevails. Upon either a wrought iron or steel center, they now generally use a steel tire. There are many forms in service, designed in accordance with the ideas of the various controlling engineering minds.

Neither country, climate, nor language absolutely controls the individuality and vital merit of each managing intellect.

As you will no doubt be more closely identified with American interests, we will confine our attention to such car wheels as are used on the railroads of this country.

Of the millions of wheels carrying the great railroad freight tonnage of America, nearly all are of cast iron, and in fact until very recent years this statement would include passenger service as well. However, the introduction of the heavy sleeping cars and general increase in weight of all classes of passenger equipment, as well as increase of speed, has forced the employment of a stronger and more elastic wheel, until now almost none other than freight cars are placed on cast iron wheels.

Our railroad authorities generally favor a plate or solid wheel, claiming that a spoke wheel is not as strong, and also that it fans up the dust, and is therefore objectionable.

As so many more wheels are used for freight than other service, that class would seem to demand our first attention.

As late as November, 1855, the superintendent of one of the then leading railroads of the country, in his annual report, said:

"Whether the present plan and construction of cars is best adapted for the cheap and safe transportation of freight is very questionable. A long or eight wheeled car is from 28 to 33 feet in length, weighs, including the trucks, 16,000 pounds, and is permitted to carry 18,000 pounds of loading."

He also stated that during the preceding year his road had moved 481,012 tons, to do which 196,939 cars were employed, so that the average load must have been less than two and a half tons.

We are now building and using cars designed to carry 60,000 pounds, and the cars will themselves weigh 35,000 pounds. Railroads formerly fined shippers placing loads exceeding ten tons on their cars. They now give him the cars and say, "Load them up." Of course this increase of both weight of cars and their loads has demanded stronger wheels. Makers have sought to meet this by progressive changes in patterns, sizes, materials used, and methods of manufacture.

Cast iron wheels with chilled treads and flanges have maintained their supremacy, because of their low first cost and the comparatively high price obtainable from the wheel makers for worn-out wheels; they mixing them with new iron, and again casting the metal into wheels.

I presume you all understand the *rationale* of iron "chilling," but I will venture to recall to you some of the peculiarities of the process.

All kinds of gray cast iron do not possess the quality, but there are those which when melted and poured against a metal mould will become hard, white, and crystalline in that portion striking against the mould. The sudden cooling causes the graphitic carbon to change into the combined state, and thus produces the "chill." Should the whole mass of melted iron be suddenly cooled, it would be all chilled. But in casting car wheels only the outer rim is suddenly cooled, so that the center is left soft and gray. A great part of the skill in making cast iron car wheels is in controlling the depth of the chill, and the manner in which it unites with or shades off into the softer iron of the plate or body of the wheel, thereby obtaining a hard wearing surface, but a more elastic supporting body.

Mr. Lobdell of the Lobdell Car Wheel Company, is one of the oldest and most successful wheel makers. In an address delivered before the New England Railroad Club in 1888 he said:

"It is possible to have such an excess of graphitic carbon and silicon in the iron that unless its chemical composition is materially changed in melting, it will not chill at all when run against a metallic mould. Other ingredients, such as manganese, phosphorus and sulphur, have more or less influence on the chilling properties of iron, and upon its strength. Many kinds of iron that possess good chilling properties are not strong, have not that degree of tenacity necessary to stand the sudden shocks and blows to which railroad wheels are subject, nor sufficient elasticity to stand the expansion of the rim by the heating of the same by the application of the brake, which often occasions the cracking of the brackets."

Many chilled wheels have run over 100,000 miles, but from 40,000 to 60,000 miles is about the service expected. You will appreciate that many difficulties surround wheel making, and that great care is required. I think I can best cover the subject by quoting from a paper read by J. N. Barr, M. of Am. Soc. C. E., Superintendent of Motive Power of the Chicago, Milwaukee & St. Paul Railroad, before the New York Railroad Club, December 20, 1888. Mr. Barr is a mechanical engineer of great intelligence and experience. He said in speaking of how to obtain a good wheel:

"A perfect wheel should answer the following description:

"1. The tread should be perfectly cylindrical.

"2. The tread and inside of flange should be perfectly smooth and free from any defect that would impair the integrity and homogeneousness of the metal forming the parts subject to abrasion, and should conform in outline to the chill.

"3. The body of the wheel should be sound and smooth, and free from any of the defects usually seen in castings.

"4. The wheel when broken should show a shell of white iron, extending inward from the parts subject to abrasion, not less than three-eighths of an inch, nor more than three-fourths of an inch, and this should not vary in thickness in the same wheel.

"5. There should not be a distinct line of demarkation between the white and gray iron, neither should the graduation from white to gray be very undecided.

"6. The gray iron forming the body of the wheel should be of medium grain, dark color, a ragged fracture, free from imperfections or white iron.

"In practice, wheels never realize the above description, their perfection being more or less impaired by the following defects:

"1 Chill cracks. 2. Rough treads. 3. Slag in tread. 4. Sweat and depression at throat. 5. Irregular depth of white iron. 6. Too great or too small depth of white iron. 7. Lack of roundness.

"There are other defects which are also common to general castings, but they will not be discussed here.

"The mould in which car wheels are cast consists in general of an iron ring, shaped on the inside to form the tread and inside of the flange. The remaining part of the mould is composed of sand as for ordinary castings. The iron ring, or chill as it is called, causes the molten metal to cool rapidly, forming white iron; and it is on the depth, hardness, and perfection of this shell of white iron that the durability of the wheel depends. In order to fully appreciate the character and importance of the defects mentioned above, a definite idea should be obtained of what takes place as a car wheel mould is filled with molten metal

"The operation of pouring a wheel, and the behavior of the molten metal and the chill, may be described as follows: The molten metal enters at the hub, spreads over the sand forming the bottom part of the mould, thence through the depressions in the sand which form the brackets into the flange. When the molten metal rises to a level with the point of the flange, it first comes in contact with the chill. It then gradually rises, covering the inside of the flange, the throat and finally the tread, until the mould is filled. The length of time consumed in pouring varies from twenty to thirty seconds, sometimes falling below the minimum mentioned and sometimes exceeding the maximum. In general, an interval from ten to fifteen seconds occurs between the time the molten metal first touches the chill and the time the chill is entirely covered Numerous experiments have been made, which show that when molten metal is poured against a chill, a contact of ten seconds is sufficient to form a solid shell nearly one-fourth of an inch in thickness. We have then, in the ordinary process of pouring a wheel, at the instant the mould is filled, the following condition of things. A shell of metal nearly one-fourth of an inch in thickness has been formed against the flange portion of the chill, and this gradually decreases, until at the top of the chill the shell is just beginning to form. The shell, as soon as it forms, starts to shrink. The chill is rapidly abstracting heat from the molten metal and starts to expand. The body of the wheel is composed of molten metal, which exerts an outward pressure against the tender red hot shell of metal, which has solidified against the chill and resists its contraction. The shell of metal formed against the chill gradually thickens and contracts, the chill itself expands, and the body of the wheel solidifies. In the operation described above it is more than likely that before the shell formed against the chill has reached an average thickness of one quarter inch, entire separation has taken place between the chill and the shell, and the hardening influence of the chill is no longer felt. The above described operation should be carefully borne in mind, as on it depends, either directly or indirectly, nearly all the defects peculiar to wheels, which will now be more fully discussed.

"CHILL CRACKS.

"This defect makes its appearance as a crack across the tread or flange, or across both. It is believed that a chill crack in the flange is caused by severe contraction, in much the same way as a thin plate of hot metal is cracked by the application of water; the chill crack across the tread is caused by the pressure of the metal composing the body of the wheels against the tender red hot shell of metal which first forms against the chill. In its origin it is properly a tear. Wheels having this defect are rarely seen in service, as it is considered a sufficient ground for scrapping on the foundry inspection. Hot and fast pouring increases the tendency to chill cracks. Cold and slow pouring prevents them. It is, I believe, universally conceded that the hotter and faster a wheel is poured, the better the quality, material being the same, and the principal skill of the wheel moulder consists in pouring his metal as hot and as fast as possible without incurring too great a loss from chill cracks. In the endeavor to avoid chill cracks, there is a constant tendency on the part of the moulder to slow and cold pouring. This leads to the production and aggravation of the defects termed rough tread, slag in tread, sweat and depression in throat, and irregular depth of white iron.

"ROUGH TREAD

is caused by undulation and bubbling of the molten metal against the chill. It shades off from being so serious as to condemn the wheel to waves and seams that are almost imperceptible. Pouring the metal at a very high temperature and very fast reduces this trouble to a minimum; cold and slow pouring aggravates it.

"SLAG IN TREAD

occurs in general as small depressed spots, with a minute cavity in the center. In wheels of ordinary good quality, it is a defect that is not at all prominent. It is also aggravated by cold and slow pouring, and reduced by hot and fast pouring.

"Rough treads and slag in tread indicate lack of homogeneity in the shell of white iron, and are the primary causes of its disintegration in service.

"SWEAT

appears as beads in the throat. Its cause is explained as follows: The shell of the metal, solidifying against the inside of the flange, commences to contract before the pouring of the wheel is completed. In shrinking it carries with it the thinner shell forming against the throat. The molten metal so nearly remelts the shell forming at the throat that it issues through in drops. Very slow pouring aggravates this defect, and fast pouring entirely prevents it. Sweat is a sure indication that where it occurs the depth of white iron is very much less than on other parts of the wheel. The depression in the throat in general extends nearly around the entire tread of the wheel; it is most decided in wheels showing sweat, and is deepest where the sweat occurs. This depression may be observed on wheels in service, which often run many miles before wearing smooth in the throat. The more decided the depression, the greater the discrepancy between the depth of white iron in the throat and in the middle of the tread. Irregular depth of white iron has a most serious influence on the service of the wheels. It is caused by irregular separation between the chill and the wheel. Experiments demonstrate that if a block of cast iron be formed against a chill, and the chill removed in less than forty seconds, the depth of white iron will be less than if the chill were allowed to remain until the block had cooled. Many measurements made of the depth of white iron on wheels, and of plain chilled blocks of the same metal, show that the maximum and minimum depth of white iron, measured at the middle of the tread, is seventy and fifty per cent. respectively of that of the block, and measured at the throat is fifty per cent. and thirty per cent. of the same. The decreased depth of white iron on the wheel as compared with the plain block is due to separation between the chill and the wheel before the chilling operation is completed, the variation around the tread to earlier separation at some point than at others. This trouble is very much increased by slow pouring.

"Too great or too small depth of white iron is a matter of the chilling quality of the metal used, although it can be modified, as shown above, by the manner of pouring. In the first case, brittle and unsafe wheels are produced; in the other, wheels which are deficient in durability. Lack of roundness is a defect which of late years has attracted a great deal of attention, and is growing in importance as capacity of cars and speed of trains increase. It is caused by lack of roundness in the chill, irregular expansion of the chill and irregular contraction of the wheel.

"To recapitulate, the following circumstances continually militate against the production of a perfect wheel: First, the tendency to chill crack, forcing the moulder to pour molten metal at too low a temperature and too slow. Second, slow and cold pouring produces rough treads, slag in tread, sweat, lack of uniformity in the depth of white iron Third, the expansion of the chill and the contraction of the wheel produces lack of roundness, variation in chill and a reduction in depth of white iron as compared with the normal chilling qualities of the iron used."

To resume, the commercial history of car wheels is the same as that of all other articles. Increased consumption has brought with it a demand for cheaper production. And increased skill and approved appliances have rendered this possible.

Railroad managers have added to the weight of their

cars, and of their loads; have increased the speed of their trains, and at the same time demand from the makers *cheaper* and *better* wheels. How to best do this has been, and is, the question. During the last two years the discussion of some of the points has waxed hot, and we will now briefly consider one of them.

Mr. Barr, in his paper just quoted from, went on to say:

"In order to obviate and reduce as much as possible the difficulties peculiar to wheel making described above, the writer has devised what is now generally known as the contracting chill. Its construction is shown in the accompanying drawing, and may be described briefly as follows:

"The ring which constitutes the ordinary chill is divided into ninety-six sections by radial divisions. These sections or blocks are held in position by an outside ring which is capable of being expanded or contracted, thus causing the blocks composing the chill to be moved radially outward or inward. By this means the expansion which occurs in the ordinary chill is entirely prevented and the inward radial motion of the chill blocks is such as to extend the time of contact between the chill and the contracting wheel within, until nearly the full effect of the cooling influence of the chill is obtained. The expansion and contraction of the outside hollow retaining ring is effected by introducing steam or cold water. A precisely similar result would be obtained by replacing the hollow ring with a mechanical chuck. The operation of the chill is as follows: When the moulder is nearly ready to pour the metal, steam is turned on through the outer ring, causing it to expand and carrying with it the chill blocks, thus increasing the diameter of the chilling surface. When the moulder commences to pour the molten metal, the steam is turned off and a current of cold water is passed through the ring, which causes a contraction of the outside hollow sustaining ring and a consequent decrease in the diameter of the chilling surface. The results obtained from the use of this device, as compared with the ordinary chill, are as follows:

"1. Chill cracks are entirely prevented. In the past five months 15,288 wheels were made in these chills, and not one was chill cracked.

"2. The restraints imposed by chill cracks being removed, the time of pouring has been decreased from between twenty and twenty-five seconds to an average less than ten seconds, and the temperature at which the molten metal is poured has been increased, so that practically no cooling or tempering of the metal whatever is required.

"3. There is an entire absence of rough treads and sweat, and the presence of slag is almost entirely prevented.

"4. There is a decided improvement in the depth of white iron and in its uniformity around the tread, the average variation around the tread being one sixteenth of an inch.

"5. The quality of the gray iron, its freedom from slag or imperfections, and the general strength of the wheel, are enhanced by the hotter and faster pouring which is made possible by the use of this device.

"6. The greater and more uniform depths of white iron on the tread afford an opportunity for truing up wheels with flat spots caused by sliding or with treads made hollow by wear, at a small fraction of the cost of a new wheel.

"7. The actual mileage results obtained from these wheels show a very decided improvement as compared with wheels of the same material made in the ordinary chill.

"8. The wheels are almost perfectly round, and maintain this roundness in service.

"There is one objection to the contracting chill wheel. The small ridges formed by the spaces between the chill blocks produce a very perceptible and unpleasant buzzing sound for some time after they are placed in service. After many endeavors to remove this objection by more perfect moulding, the writer has come to the conclusion that the only practicable way of avoiding this difficulty is to trim the ridges off with a grinding machine.

"The defects or causes of wheels failng in service are comparatively few, and may be classified as follows:

"1. Failure of the chill. 2. Wear on the rail. 3. Cracked and broken. 4. Sliding.

"The wheels which are condemned under the head of failure of the chill may be divided into four classes:

"1. Shelled out. 2. Comby. 3. Seams. 4. Worn flat.

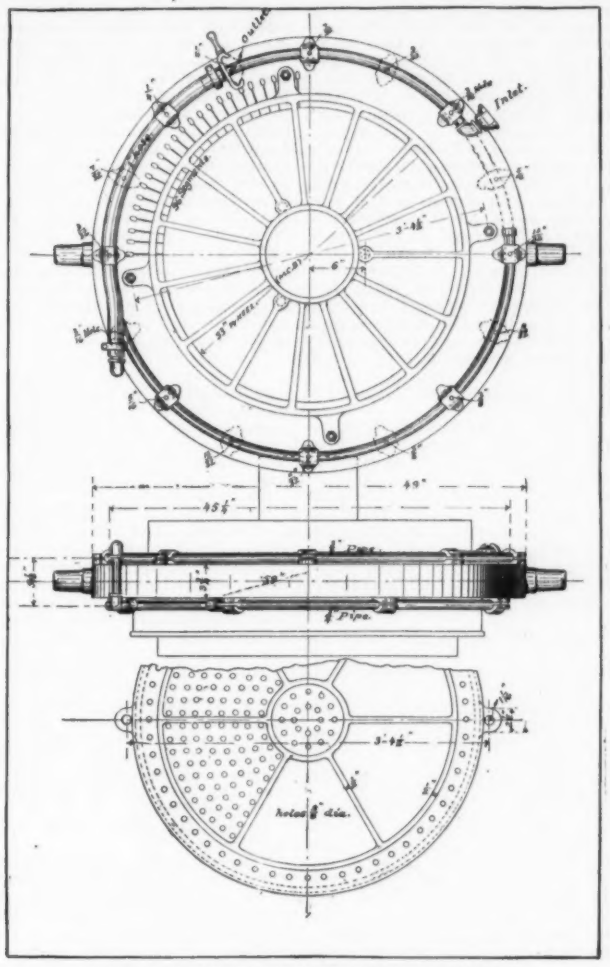


FIG. 1.—BARR'S CONTRACTING CHILL.

"The defect called shelled out occurs in the tread, generally in the form of circular spots with a raised center, varying in diameter from one half to two and one half inches. It manifests itself more frequently in wheels exposed to heavy and fast service, and is rarely seen in ordinary freight car wheels. It is due to a defect or lack of homogeneity in portions of the tread,

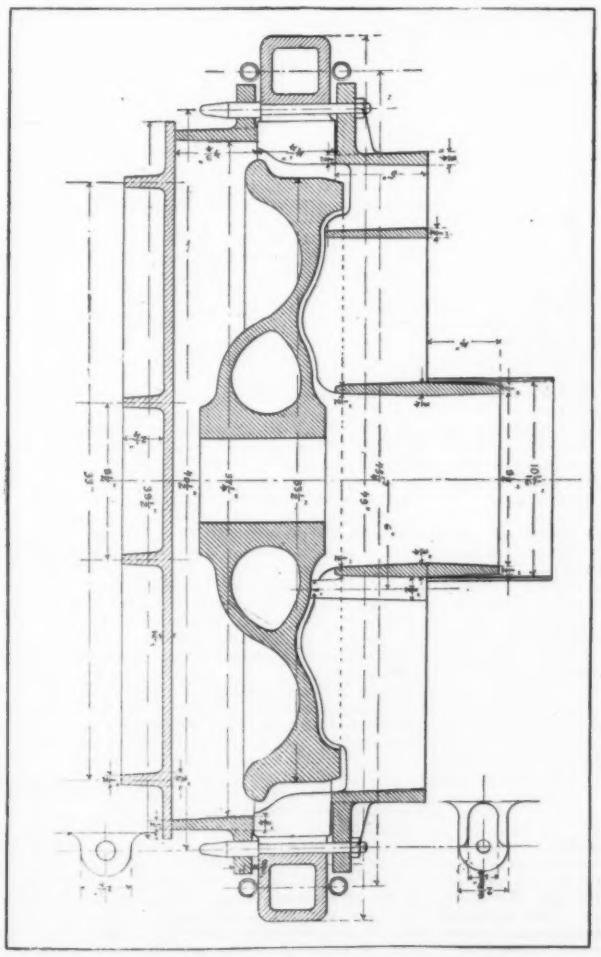


FIG. 2.—BARR'S CONTRACTING CHILL.

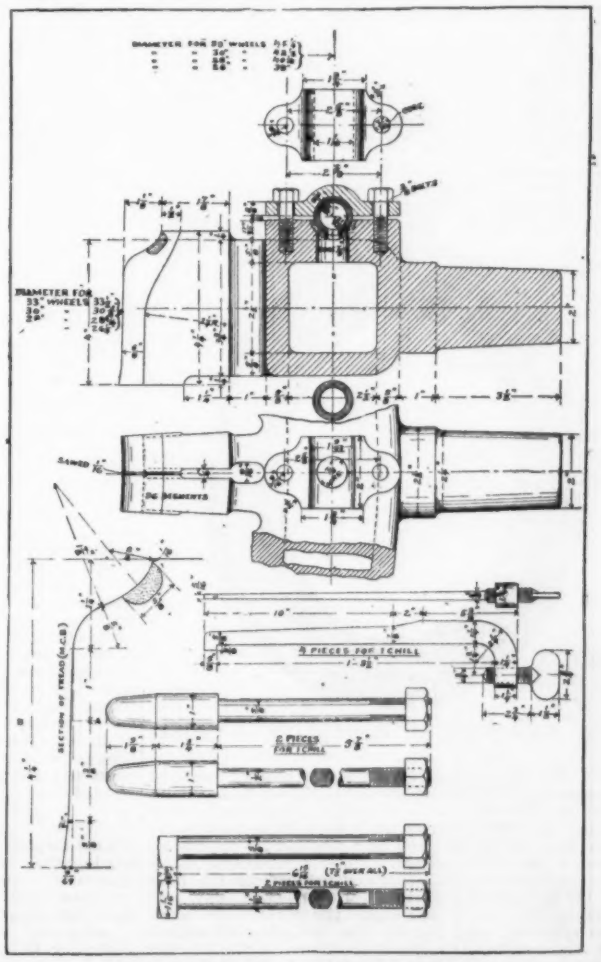


FIG. 3.—BARR'S CONTRACTING CHILL.

and the temperature and rate of pouring has much to do with the formation of this defect, more so than any other cause, hot and fast pouring reducing this cause of loss to a minimum. The defect designated by the word *comby* appears in the form of clusters of small rounded cavities. It is due to very cold and slow pouring, producing slag in tread, and is not found to a great extent in wheels made of good material when properly poured. Seams make their appearance as cracks, extending around the tread of the wheel. When several of these seams occur near together a portion of the tread drops out between them, causing a flat spot. There is every reason for believing that the development of this defect is due to the seams which may be originally seen on the treads of new wheels, and that the lack of homogeneity, indicated by the seams and waves in the tread of new wheels, finally develops into definite cracks extending through the white iron when exposed to service. The defect termed worn flat explains itself. The name for this defect now adopted by the Master Car Builders' Association is worn through the chill. This term is much more descriptive and much more definite. It is caused by the lack of uniformity in the depth of white iron around the tread of the wheel, as referred to above. While no wheels have an absolutely uniform chill, at the same time the trouble from this lack of uniformity and the tendency of the wheel to wear flat is very much aggravated by slow pouring.

"The causes of failure of wheels under the head of wear on rails are as follows:

"1. Worn tread. 2. Tread worn hollow at flange. 3. Tread worn hollow from flange. 4. Worn flange. Failure in these four forms cannot be said to be due to defects, and it may be considered a useless refinement to make four divisions, but some very important information is obtained by doing so. The term "worn tread" indicates that the wear has been uniformly distributed over the tread, not confined so as to form a groove. When one wheel on an axle is in this condition, the mate wheel is generally in the same condition. It shows the following desirable conditions:

"1. The wheels were accurately of the same size when mounted.

"2. Both wheels possessed the same wearing qualities.

"3. Trucks and running gear are maintained in first class condition.

"4. The mileage of worn tread wheels is generally considerably above the average.

"When one wheel is worn hollow at flange, the mate wheel is generally found worn hollow from flange. It indicates imperfect mating, irregular wearing qualities in the wheel, or badly constructed trucks. In the writer's opinion, irregular wearing qualities in the wheels mated together is the principal cause of this wear. Worn flange in one wheel is accompanied by worn hollow from flange in the mate wheel. It indicates an aggravated condition of the causes which act to produce the two last mentioned kinds of wear.

"As to sliding, this defect is clearly a matter of manner of handling the wheel in service, and is independent of the quality of the wheel. It occurs in two forms, designated by the terms flat sliding and comby sliding. The term flat sliding explains itself. The term comby sliding is used to designate a condition of the sliding spot in which the heat from sliding cracks the white iron under the flat spot, so that the metal drops out in small pieces. This defect has no relation whatever to the defect described above as comby. Close attention to the adjustment of brakes and manipulation of the same, both in passenger and freight service, is the only means of reducing this source of loss.

"Cracked and broken wheels occur in various forms, and the following terms are used in reporting them:

"1. Cracked or broken flange. 1. Cracked or broken rim. 3. Burst. 4. Cracked brackets. 5. Cracked plates. 6. Broken in pieces.

"These terms explain themselves and do not call for any special remark."

We will now consider the Whitney contracting chill. This is the casting, turned and finished ready for use. In a chill for a 33 inch wheel, there are 100 of the fingers or divisions. The Barr chill has about the same. Mr. Whitney uses asbestos in casting his, and the spaces between them are one hundredth of an inch in width. This will allow the chill to contract nearly an inch in circumference, and the Whitney Company claim that there are not any perceptible marks or ridges on the wheel treads. These contracting chills are constructed so that the expansion from the heat will be toward the center, and thus the chill will follow up the wheel and make the "chilling" work more effective, and permit the designing of wheels with thicker treads to resist the blows of the heavier rolling stock. And their advocates claim that such action occurs. On the other hand, wheel makers, including such men as Mr. Lobdell and Mr. Griffin, deny that such action is possible. Mr. Lobdell said during a discussion on this subject:

FIG. 4.—THE WHITNEY CONTRACTING CHILL.

"Mr. Barr stated that in ten seconds after molten iron struck the chill that a depth of chilled iron one quarter of an inch in thickness was formed. I would like to ask Mr. Barr if he has any idea of what the increased temperature of the chill would be in ten seconds. He predicates the value of a sectional chill, and so does Mr. Whitney, on the theory that the chill expands inwardly and meets the contraction of the wheel as it contracts. Now to do that there must be an increase in the temperature of the chill. Some experiments were tried in our foundry which resulted as follows: The temperature of the chill before it was poured was forty-eight deg. In thirty seconds after that, and after the wheel was poured entirely, it was but fifty-two degrees, the temperature having been increased about four degrees. Now, that was long after the wheel was all formed and the chill all formed—thirty seconds on the outside. Now, you cannot expand the inside until you expand outside. Mr. Chairman, I am one of the kind of fellows who have an opinion of their own, and I think a man who has not an opinion of his own is a fool, but a man who never changes his opinion is a bigger fool, and I am ready to change my opinion when the thing is demonstrated."

To it Mr. Barr replied:

"In reference to the matter of the metal solidifying a quarter of an inch in ten seconds, I have, I suppose, made a hundred tests of that by pouring a block of metal against a chill, and removing the chill in ten seconds. And I simply say that unless my eyes deceive me and my rule belied itself, what I said is correct without the least matter of theory about it."

Mr. Lobdell replied:

"I have not the least doubt of it. I have often had a wheel when half full to run out and leave a chilled crust around there of a quarter of an inch or more in thickness. I have had a wheel to run just as it was full, and it would leave the entire straight flange all of a certain thickness. I have had occasionally a chilled roll, weighing from twelve to fourteen thousand pounds, to break out at the bottom and leave a chilled ring from one inch to an inch and a half in thickness; but I doubt that Mr. Whitney's chill meets the contraction of the wheel to any degree; and as for the roundness of the wheel, we have had probably from forty to fifty thousand wheels inspected by the Pennsylvania and our inspectors during the past year and a half, and they have never discovered a wheel that was over one sixty-fourth of an inch out of round. We have no trouble with the sweating of the flange of the wheel. Mr. Barr knows that."

In this connection Mr. J. R. Whitney gave the following:

"Some time ago I made some experiments with Salisbury iron. I found the shrinkage of the iron was 0·15 of an inch in a foot. That was the natural shrinkage of the iron. I cast two wheels of that lot of Salisbury iron. One of them was cast in an ordinary chill, the other in the contracting chill. The ordinary chill when cold measured in its circumference 96·75 of an inch. The wheel cast in it when it was cold measured 95·625 of an inch. The Salisbury iron shrunk as we have seen fifteen one-hundredths of an inch in a foot, which carried out gives 1·3 of an inch in the circumference. If there had been no expansion in the chill, the wheel ought to have been the full size of the chill, less the natural shrinkage of the iron, or 96·75 minus 1·3. The wheel should have been 95·45 of an inch in circumference, but it was actually 95·625. It was larger than it ought to have been from the natural shrinkage of the iron. The explanation of that is that the chill expanded before the wheel solidified. When the wheel solidified, it filled the chill, which at that time measured more than 96 75, and the natural shrinkage of the iron brought it down to 96·625. Now, after a good many experiments, I have demonstrated this—I presume others have found the same thing. Liquid iron follows very much the same law that water follows in regard to solidifying. If you cool water down from any temperature you please to about forty degrees, it contracts, becoming smaller and smaller in volume. When it goes down to forty degrees temperature, however, if you still continue to reduce the temperature, it begins to expand. At thirty-two degrees, when it solidifies, it expands with force and breaks the vessel in which it is contained. Now, iron does precisely the same thing as it cools down to the point of solidifying. The moment it becomes solid it expands, just as water does, and fills the mould perfectly to whatever size and shape the mould has expanded to at that time. So that the wheel expands to fill the increased size of the chill; then begins to shrink from that size. Now, in the contracting chill we had this result: The circumference of the contracting chill was 96·625, measured when it was cold. The wheel cast in it measured 95·25 when cold. Now, if the wheel simply had the shrinkage of the iron, 1·3, it should have been 96·625 minus 1·3, or 95·325; it should have been a larger wheel than I got. My wheel was smaller than the natural shrinkage of the iron would make it. How did it get smaller? The segments had moved in just as Mr. Barr describes, and the chill was actually smaller in diameter, when the wheel solidified, than 96·625. It was that size when it was cold, but when the wheel solidified, it was of a smaller diameter. The contraction is not very much in this particular case; with other iron it is more. It is perfectly evident, however, that as the wheel was smaller than it ought to have been by the natural contraction of the iron, the chill remained in close contact with the wheel during the whole process of the chilling. In consequence, the depth of chill is perfectly uniform all around the wheel, and seventy-five per cent. of all the wheels we have broken up within the last two years did not show any more variation in the depth of chill than in this case.

(To be continued.)

THE improved artificial ivory is obtained by kneading together lime, phosphoric acid, calcium carbonate, magnesia, alumina, gelatin, and albumen, in such proportions that the resulting mixture has the same chemical composition as natural ivory. The material is subjected, while hot, to great pressure, and after maturing for some weeks it can be cut, turned, and polished in the ordinary way.—*A. and S. De Pont, Paris, France.*

THE GREAT SALT DEPOSITS OF KHEWRA, IN THE PUNJAB.

By E. RODGER.

IT is well known that the Indian government derives a considerable revenue from the duty upon salt, amounting to about 6,000,000*l.* annually, and with a view to the correct realization of this income, exercises a jealous supervision over all the sources for the supply of this substance. These sources of supply are various.

Large quantities of salt are imported into India from this country, a considerable amount is obtained from sea water by means of evaporation by solar heat, and similar means are used to prepare it from the waters of salt lakes, notably the Sambhur Lake, near Jeypore, in the Rujputana district; and, lastly, there are, in the northwest corner of the Punjab, the extensive deposits of rock salt which are the subject of this paper. The deposits are situated in the Salt Range, a chain of hills which may be considered as one of the spurs of the Himalaya mountains, although hardly connected directly with them, and the mines are not very far from the battlefield of Chillianwallah. There is now a railway which runs up almost to the entrance of the mine, by means of which Khewra can be reached in about twelve hours from Lahore.

The hills referred to, which seem to be singularly barren, rise boldly and abruptly from a level alluvial plain, through which flows, at no great distance from the base of the mountains, the river Jhelum, one of the tributaries of the Indus. Khewra itself is a small village, built well up the hillside, depending entirely on the salt mines for its existence, and almost entirely inhabited by the miners and their dependants.

One mine only is being wrought at present; it is a very extensive one, called the Mayo mine, which name was bestowed on it in memory of a visit paid by Lord Mayo during his tenure of office as governor-general.

So far as I could judge, the mine seems to be very economically worked, except as regards the small salt, to which, however, I will refer later.

The manner of working is as follows:

On the salt being reached, which is done by driving a tunnel for a short distance horizontally into the hillside, a chamber is cut in the salt, 45 ft. deep from front to back, of a convenient height and length (varying in the early stages with the height and width of the salt deposit).

Then a wall of the solid salt, 25 ft. thick, is left standing, with only a twelve foot gallery running through it, and another 45 ft. chamber is commenced beyond. The wall of salt is left, of course, to support the roof. The workings are carried on at various levels, for the salt runs in layers for 900 ft. above the lowest level at which it is worked, that is to say, above the level of the lowest entrance to the mine. It is arranged that the chambers in the various levels shall coincide with one another, and thus it happens that when one chamber is worked out, another is commenced directly above it, and being worked downward, in time the two form only one chamber, but of double the usual height, and in some cases more than two chambers are thus run into one.

Some of the chambers formed by this process are 180 ft. high and 45 ft. broad; one which I saw was so high that blue lights burned below totally failed to illuminate the upper part at all, and to show the height, a small fire balloon was made use of. When I say that there were upward of twenty chambers open, several of them as large as this, besides the galleries and small cuttings, some idea may be formed of the vast amount of salt which has been removed, and this without doing more than touching the outskirts of the deposit.

About 1,200 laborers are employed in all, and they average about eight annas a day of wages on piece work.

The workers are all Mohammedans, and they have a number of curious customs, one being that they work only nine months in the year, the remaining three being spent among the higher hills in holiday making.

The salt is blasted out by means of powder and the lumps are then cleaned if need be, and are afterward broken to a convenient size.

The tools used are few and simple. A long iron bar or "jumper" for boring the blast hole (which the miners do by thrusting the bar with both hands, not by striking it with a hammer as we would do), a small hammer for loosening the jumper when it jams, and a scraper for clearing away the powdered salt from the hole, the small dust thus obtained being used for tamping.

A tramway runs through the principal galleries of the mine; it is worked by coolies, who are found to be more economical than mechanical haulage, and large numbers of women are employed as porters to carry the salt from the working spots to the loading stations on the tramway lines. As is usual in subterranean workings, the temperature of the mine is very constant, warm in winter and cool in summer. At the time of my visit in the month of February, the thermometer was about 86° F. inside the mine, and I am told that this temperature is hardly ever much exceeded, so that during the hot weather the officials retire into the mine for the sake of coolness while doing office work, which at other times is done above ground.

The small salt to which I referred in the beginning of the paper consists of the small splinters and fragments produced by the blasting and by the trimming of the lumps. It is unsalable they say, and is used to fill up old workings and prevent collapse. This seems at first sight to be a great waste, but if these disused chambers must be filled up, perhaps this small salt is the cheapest material at hand.

The deposit of salt runs much deeper than they work, as it is not considered advisable to work below the level of the plain; first on account of water, and secondly to avoid the extra labor of carrying the salt up to the outer level. The deposit is exceedingly compact and solid, exhibiting very few cavities or fissures, and the mine therefore lacks the picturesqueness of some of those salt deposits in which these abound.

So far as I know, only one cavity of any size has

been found, which, like most similar ones in other salt mines, is partially filled with brine, and has the roof covered with crystals, but it is only of small extent.

I did not see any analyses of the salt, but the superintendent of the mine informed me that the best samples contained about 99 per cent. of chloride of sodium and one per cent. of all impurity, including water and insoluble matter, while the worst contained about 96·4 per cent. of chloride of sodium and 3·6 per cent. of impurity, mostly insoluble matter. I may here mention that fine crystals are rare, and that when extracted the mineral is of a pale pinky red hue, when viewed in large masses; when finely ground, it is as white as snow. The duty upon salt at the time of my visit was Rs. 2·8 per maund (one maund equals 82¼ lb. nearly), while the cost of the salt itself at the mine is a mere trifle. I need, therefore, hardly point out that smuggling salt would be a very profitable business, and therefore, to prevent any contraband traffic, the mine and its approaches are heedfully guarded by watchmen, and a number of means are used to prevent pilfering, etc.; but these precautions need only be alluded to in passing.

When removed from the mine, the salt is stored in a store near the railway station, to which a siding runs. The salt is packed in bags, and transported in closed trucks, the doors of which are locked, to prevent the contents being tampered with.

In conclusion, I may say that these mines have been worked for many years, how long is uncertain, but they have been a monopoly of the Indian government since the annexation of the Punjab in 1849, and for long before that date were worked by the Sikhs.

Lastly, I wish to take this opportunity of recording my indebtedness to the courteous superintendent of the mines for the kindness with which he received me, an unexpected visitor, at an awkward time, and for the care which he took that I should be shown everything of interest.—*Jour. Soc. Chem. Industry.*

IMPROVED FLAX SCUTCHING MACHINE.

WE had recently an opportunity of inspecting a new flax scutching machine, which has been invented by Arthur Spiegelberg, of Dundee. Before we describe the machine, it may be well to state that when flax is pulled the stalk may be said to be made up of three distinct parts. In fact, it resembles a beech tree; there is first the wood, then the bark, and lastly the glossy varnish of the bark. The woody matter in flax is of no value; the difficulty is how to get rid of it, and to save the bark. To accomplish this the flax must be retted, and it is either spread over a field and exposed to the weather for some time, which is called "dew retting," or the straw is steeped in water. In a short time the vegetable part rots, the gum on the outside dissolves and the stalks are taken out of the water and dried. But the wood is like a fixed finger inside a glove, and, although weakened, has still to be removed. Scutching is the process by which the wood is removed and the outside skin saved. The difficulty is to get the woody part out without injury to the skin, which is *the* valuable part of the plant and forms the flax fiber. There are four methods of doing this. The first is by striking the flax repeated blows, then taking it in handfuls, holding it over a wooden rest, and striking it sharp blows with a wooden blade. The second plan is to run the retted straw through fluted iron rollers, and when the heart is thus broken into short bits, to take the straw in handfuls, and hold it against two end blades rapidly revolving upon a shaft. The process known as the "Cardon" process, and which promised great things a short time ago, consists in pricking the straw with needles. This cuts the straw into lengths so small as to make it practically dust. The straw comes easily away. But it is obvious that the skin is damaged at the same time, because the heart of the stalk must be got at through this outer skin.

The breaking machine of Mr. Spiegelberg is a novel departure from the older processes. The flax straw is fed into the machine, one end always overlapping the preceding one. Heavy fluted rollers flatten the tubular stalks, which action does not spoil the fiber, but only takes the resistance out of the straw. Then the flax proceeds to the small rollers, lightly fluted, just sufficient to obtain a thorough grip of the flax, and by means of suitable mechanism these rollers receive a lateral or shaking motion which bends the stalks and allows the wood to fall out, and also prevents the outer skin from becoming crushed or cut, as is the case with the needle points, or the series of fluted rollers—run at a high speed—of other machines. The fiber then passes to the second part of the machine as illustrated herewith, which somewhat resembles an intersecting heckling machine. The "strike" of flax is secured between a pair of India rubber gripping rollers C C^1 which bring it into contact with a pair of rapidly revolving beaters D D^1. After this operation has gone on for a given time, the beaters are caused to revolve in the opposite direction, the gripping rollers C C^1 and E E^1 are respectively automatically opened and closed in the interval by means of cam bars, F F^1, the cams, G, and levers, H.

In this manner both ends of the strike are sufficiently operated upon before they are allowed to proceed downward to the delivery roller, J J^1, and thence to the delivery apron, K. L is the first motion shaft, carrying fast and loose pulleys, connected to similar pulleys on the shaft, M, from which the beaters are driven.

The taking-in rollers, B B^1, derive motion from suitable gearing, N, which is so constructed as to allow itself to become automatically disengaged upon the reversal of the machine.

The principal part of the process, however, is that involved in the breaking machine, which cannot be substituted by hand or other process, while the cleaning might be done in the ordinary way; in fact, when the flax is well retted the breaking is done so completely that a little handling cleans the fiber entirely from all shove. The two machines may be worked separately.

It is obvious that, the fiber being uninjured, there is a much larger yield of fiber, and the heckle gives far more yield in line. About the importance of scutching there can be no question. Vast countries produce grasses and fibers which are of the highest value.

The difficulty always has been to separate the fiber from the gummy exterior and from the inside pith or wood. This machine may therefore become of the very highest importance, and further trials on a practical and commercial scale will be awaited with very deep interest by those connected with the flax trade.—*Industries.*

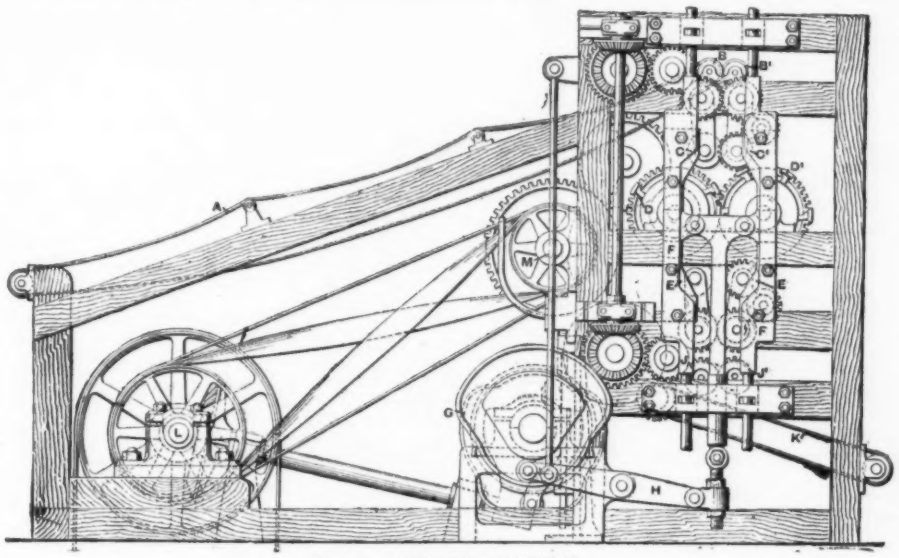


FIG. 1.—SIDE ELEVATION.

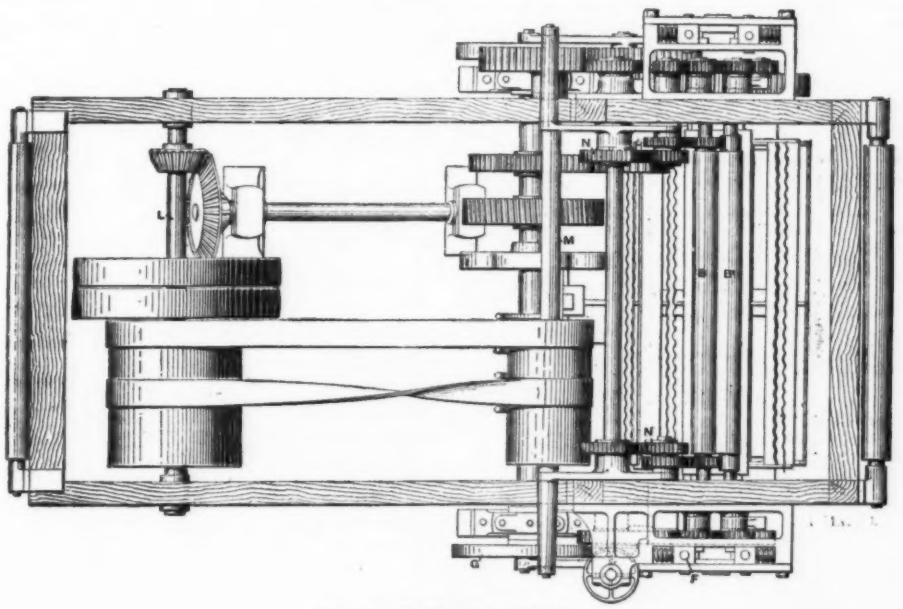


FIG. 2.—GENERAL PLAN.

SULPHITE PULP IN AMERICA.

THE following abstract is from a letter on the above subject by Mr. Waldemar Thilmany, Kaukauna, Wisconsin, U. S. A., on March 13, to the *Papier Zeitung*, No. 35, 1st May, 1890.

At the Thilmany Pulp and Paper Works, the Mitscherlich sulphite process is at work. The first mill using this process was started at Alpena, Michigan, in November, 1886, with a daily output of twenty tons of 2,000 lb. per ton.

It interested him much to find out how the different kinds of wood would behave in the sulphite process, and he therefore allowed a boiler full of each of the following different woods to be digested, viz.: Beech (*Fagus Sylvatica L.*), birch (*Betula Alba*), maple (*Acer Pseudoplatanus* and *Acer Platanoides L.*), American larch (*Pinus Larix L.*), aspen (*Populus Tremula L.*), black poplar (*Populus Nigra L.*), red fir (*Pinus Picea*), spruce or white pine (*Pinus Abies*), yellow pine (*Pinus Sylvestris*).

The wood was freshly felled, and had a diameter varying from five to eight inches. It was cut into disks of 1¼ in. thick, and then digested whole with a solution of 5½° B. by the Mitscherlich methods. All of these woods with the exception of the *Pinus Sylvestris* (which remained hard in the center), were well boiled and completely soft.

Beech, birch, and maple yielded snow white sulphite pulp, whose fiber, however, was considerably shorter than that from the red or white pine (*Pinus Picea* and *Pinus Abies*), and consequently they did not yield so strong a paper.

Afterward, some boilers full of larchwood ("tamarack") were digested, and the pulp run off on a cylinder machine in the same way as it is sent to the paper mills. The fiber appeared good and strong, but the color was mottled, *i. e.*, it varied from dark brown to citron yellow.

At present the seven mills in America working the Mitscherlich system produce daily about 70 tons of pulp, and use exclusively spruce or white pine wood (*Pinus Abies*).

Two larger mills situated in the Fox River valley, with eight digesters, each 14 ft. diameter and 42 ft. long, produce daily 20 tons of pulp, while another mill at Madison, Maine, has 20 digesters of the above size, equal to a daily output of 20 tons pulp.

Sulphite pulp prepared by the Mitscherlich process is clean if the wood be properly sorted. There is apparently a difference in the strength of the fiber obtained from American spruce by the sulphite method as compared with imported sulphite pulps, even those made by Mitscherlich system in Europe. Tests of raw American-made pulp and newspaper made from it, in a paper mill belonging to Mr. Thilmany's brother, revealed the fact that from 10 to 15 per cent. more imported pulp had to be used to obtain the same results as regards strength.

The pulps imported to America are frequently mixed, so that the paper maker is not always provided with the same make.

How this occurs the importer only knows. This he keeps secret, and makes many untrue assertions regarding it.

The paper maker who has hitherto made good newspaper from 20 per cent. sulphite and 80 per cent. mechanical wood pulp, suddenly finds that his paper is much weaker, and consequently many complaints pour in upon him. He then investigates his pulps, and finds among them the most diverse qualities.

All sulphite pulp made in America and manufactured into newspaper is used for this purpose in the unbleached state.

HELIGOLAND.

THE diminutive island in the German Ocean which it is proposed by England to cede to the German Empire, in consideration of great and valuable territorial concessions in East Africa and of an undisputed British protectorate of Zanzibar, consists of a piece of rock and a piece of sand, having a total area of three quarters of a square mile. It has never been treated by the British government as a defensive position of any naval or military value, nor has any attempt or proposal been made to arm it as a fortress. It was captured by the British in 1807, and formally ceded to Great Britain under the treaty of Kiel in 1814. Heligoland was much larger at one time than it now is, Sandy Island having formed a part of it until 1720, when they were separated by a storm. It is on Sandy Island that the sea bathing, which is considered to be the finest in the world, takes place. The reefs round the islands are very dangerous, and wrecks were at one time of frequent occurrence, but an excellent lighthouse with fog signal station renders such disasters rare. A rocket station and a life-saving apparatus have also been es-

tablished, and are worked by the English and local coastguard.

The main island consists of a red sandstone cliff, about 170 feet high, with, except in one part, inaccessible sides The town is divided into two parts, the underland on the beach containing the bathing establishment, "Conversations" house, theater, coastguards, barracks, and hotels. The Oberland, to which access is obtained by a flight of 192 steps, and by a lift worked by steam power, contains the largest number of houses, including a church, schools, governor's residence, and lighthouse. The resident population, nearly all Germans, are occupied in fishing, which is carried on by a fleet of open boats, from March to June and from October to January. The fish caught consist principally of haddock, with a few cod, and sometimes a turbot, also lobsters and oysters. Many German visitors go to Heligoland in the summer.

A "HOME MADE" ELECTRIC MOTOR.

ONE of the prettiest, most useful, and perhaps the best application the amateur can make of his electrical knowledge is in making a motor for driving a sewing machine; and, as such a motor need be but of small size, well within the compass of any ordinary mechanic, and can be made cheaply, without any outlay except for the wire and a few pieces of iron and brass that can be had anywhere, the following description of a successful model is given to help out those desirous of such a motor.

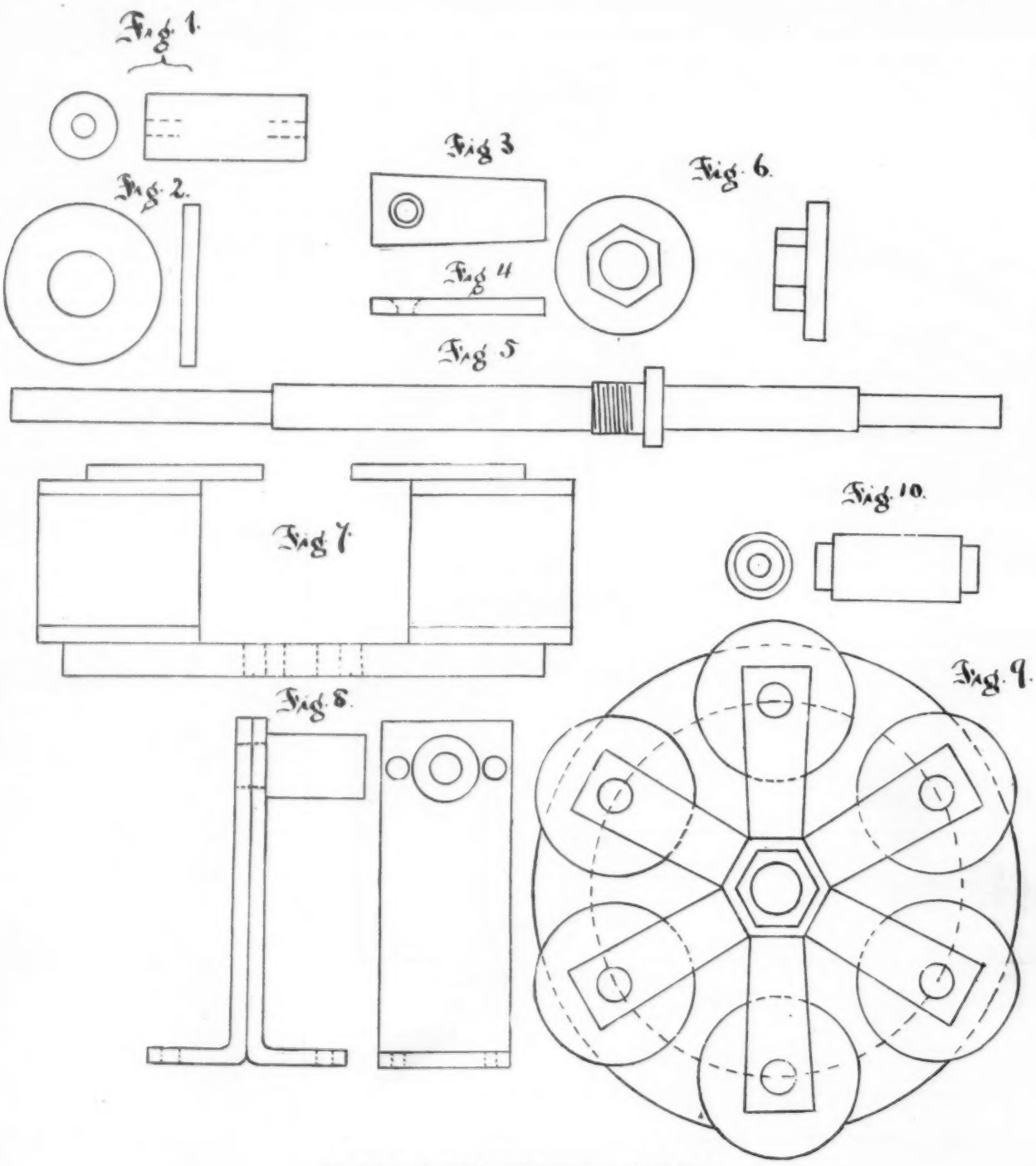
The drawings are all full size. Hence no dimensions are given, except where necessary in the description.

Eight pieces of good, *soft*, round iron, of size and length shown in Fig. 1, are first got out, turned up square at each end, and each end drilled and tapped to receive either No. 6 or No. 8 machine screws. Care should be taken to have *all* of the same length exactly, as will presently appear.

Sixteen round wooden or hard rubber disks are then got out, of the size and thickness shown in Fig. 2. They should be drilled with a central hole to make a *tight* fit upon the iron cores above mentioned, and each core should be fitted with a disk at each end. We thus have eight spools, each with one inch clear space for winding the wire.

A circular iron plate is now to be got out, three and three-quarter inches in diameter, and any convenient thickness, so long as it is thick enough to be rigid. It need not be more than one-eighth of an inch thick, if a solid plate. It may be either of wrought or cast iron, whichever is best available. If of cast iron, however, it should be of the "soft" variety. A suitable plate may be built up, in want of a solid plate, from disks of stove pipe iron cut out with the shears, and fastened together in sufficient number to give the thickness necessary to give a good rigid plate. The screws that are used—to be described presently—to fasten the spools to this plate can be partly depended upon to help fasten these disks together.

Whichever form of plate is used, it should have a central hole about three-eighths inch diameter, and the edge and faces should be made to run perfectly true. Six holes are to be laid off equidistant apart, upon a circle two and seven-eighths inches in diameter, and these holes are to be drilled to receive the screws that fit the ends of the cores.



HOME MADE ELECTRIC MOTOR.

The shaft, shown in full size and shape in Fig. 5, may now be got out. It should be of machinery steel, as the easiest working material that is suitable. At first it should not be fully turned down, but only so as to form the collar and threaded part, leaving the rest until later. The shaft may now be used as an arbor, the circular plate be mounted thereon, and held in place by the flange nut shown in Fig. 6. This manner of mounting is particularly applicable for the built-up plate, as the collar and flanged nut give good true surfaces between which to clamp the plate. If the plate is solid, the shaft may be turned down to a collar, and a tight driving fit instead of the threaded part. This will be found all sufficient to hold it in place.

The spools may now be mounted upon the plate, and the whole spun in the lathe to see that everything runs true, and, when everything does run true, it may then be laid aside.

Eight pieces of *soft* iron of the form and size shown in Figs. 3 and 4 are then to be got out, and drilled as shown for a *countersunk* screw head. These are for pole pieces to the spools upon both the armature and field magnet. They are to be fastened upon the front ends of the spools, as shown in Fig. 9 for the armature spools, and in Fig. 7 for the field magnet spools.

A yoke piece, $\frac{1}{2} \times \frac{1}{4}$ in. and the length shown in Fig. 7, is then to be fitted to two of the spools, to form the field magnet. This should have a *central* hole $\frac{1}{4}$ in. diameter, drilled through, *fair and square* with the faces of the bar. Fig. 7 shows the field magnets all mounted up, and with pole pieces in place.

To form the uprights or standards, four pieces of heavy sheet brass cut to *finish* 1 in. wide are then got out long enough to bend at right angles at one end, so as to form the standard as shown in Fig. 8. When bent to a right angle, two of these pieces may be fastened back to back, either by soldering or by small screws, so as to form a complete standard, with foot each way as shown. The feet are to be drilled for No. 6 or No. 8 machine screws, as indicated by dotted lines.

A piece of brass rod is then to be turned down to form the journal box. A hole should be drilled through the upper part of the standard, and the end of the brass rod be turned down to a snug driving fit. The brass rod should, at the same time while being turned, be drilled through from end to end with a $\frac{1}{4}$ in. hole. The brass rod may then be fastened into the standard by riveting or by soldering, and will then form a good standard and box, with the axis of the box parallel to the line of the foot.

This boxing will be found not absolutely essential, but a great addition to the completed motor. The shaft should have good long bearings to run smoothly and without undue wear, and the bearings shown are none too long to give good support to the shaft.

Both bearings and boxes having now been finished (and they are both alike), the shaft may now be finished by turning the journals down to fit the boxes. The amateur will find this mode of procedure the best to get a good fit. The holes having been drilled, they are finished once for all. If the shaft has been turned up complete beforehand, these holes when drilled may or may not fit the journals, and the chances are that they will not. But by fitting the journals last they can be

turned down and polished to as fine and close a fit as one wishes. In this case they should be made with a tight fit at first, and until the uprights have been accurately fitted to the bed plate, and then the journals may be eased off a bit to give a good smooth run in the boxes, so as not to rub or bind, and yet not shake.

One of the standards is now to be drilled with two holes by the sides of the boxing, as shown in Fig. 8, and the yoke of the field magnet be fitted and screwed thereto, so that the journal may run free through the central hole already bored in the yoke.

The bed plate is a piece of heavy sheet brass or other metal fitted with screws, as shown in Figs. 11 and 12, to fasten it down to a wooden base. The standards are to be put upon their journals, and then be fitted accurately to this plate, so as to be fair in line with the center line of the plate. This bed plate will be found well worth the trouble of making. If the standards are fastened direct to the wood, then there will be trouble from binding every time the wood changes shape from warping or twisting. With a good metal plate this is all overcome once for all. The writer has tried it both ways, and no matter how well seasoned the wood, the bearings would finally get out of line.

A wooden base of the form shown may now be got out upon which to mount the metal base plate, as well also to give means of attachment for binding posts, etc., and to conceal the wires from the field magnets, that run underneath, and are secured in grooves.

The commutator may be of the usual form, with six bars, and is mounted as shown in Figs. 11 and 12. A good commutator may also be made as described in a previous article upon small motors, the flanged cylinder being cut up into six pieces, instead of two. But any form of six part commutator will do, and there have been so many described already that no description is here needed.

The same with the brush holder. The form shown in Figs. 11 and 12 explains itself.

The spools can now be wound. The six that form the armature are to be wound with No. 18 double cotton-covered magnet wire, in the usual manner, both ends to be brought out at the plate end of the spool.

If desired, holes may be drilled through the plate of the armature, and insulated by drawing in small rubber tube and the wires passed through these holes. Or the wires may be carried over the edge of the plate down to the commutator. The former method is the most shipshape, the latter the simplest.

The armature spools may now be finally fixed in place, the pole pieces adjusted, and the connection to the commutator be made.

There are two methods of connecting. One is to look at the armature as three electro-magnets, each of which is an armature, giving three armatures to the motor. In this case the *inside* ends of diametrically opposite spools are to be fastened together, and the *outside* ends of these spools be fastened to opposite bars of the commutator. This will give a motor that will work, but there are four spools idle all the time, and it is not so good as the following connecting.

The *inside* end of one spool and the *outside* end of the next are fastened to one commutator bar. The *inside* end of this second spool and the *outside* end of the third are fastened to the next bar, and so on all around. This connects up all the spools so as to be in parallel, and they are all active all the time, except when the shift is made by the brushes upon the bars, the same as in the Gramme ring.

The motor from which these drawings were made has the field magnet cores wound full with No. 24 cotton-covered wire, and the motor is connected up as a shunt. This can be followed if so desired, as the motor is a powerful one. But a series winding can also be made by winding the field full of No. 18 wire the same as the armature.

The pole pieces and magnet ends should evidently all lie fair and true in parallel planes, so that the face of the armature can be made to travel as close as possible to the face of the field magnets, and not rub or strike. It was for this reason that the pole pieces were fastened with countersunk screws. The space shown in Figs. 11 and 12 between armature face and field magnet face is clearance enough if everything runs true, as it should.

The armature spools should be carefully wound so as to get the same *weight* of wire in each spool. This will come true if the lengths are the same. The armature is quite heavy, and should be well balanced to avoid vibration that will certainly occur if it is out of balance.

The pulley may be of the size and form shown if for a round belt, and the ordinary form if for a flat belt.

With this little motor, which weighs five pounds and three-quarters, with heavy double wooden base, the

Fig. 11

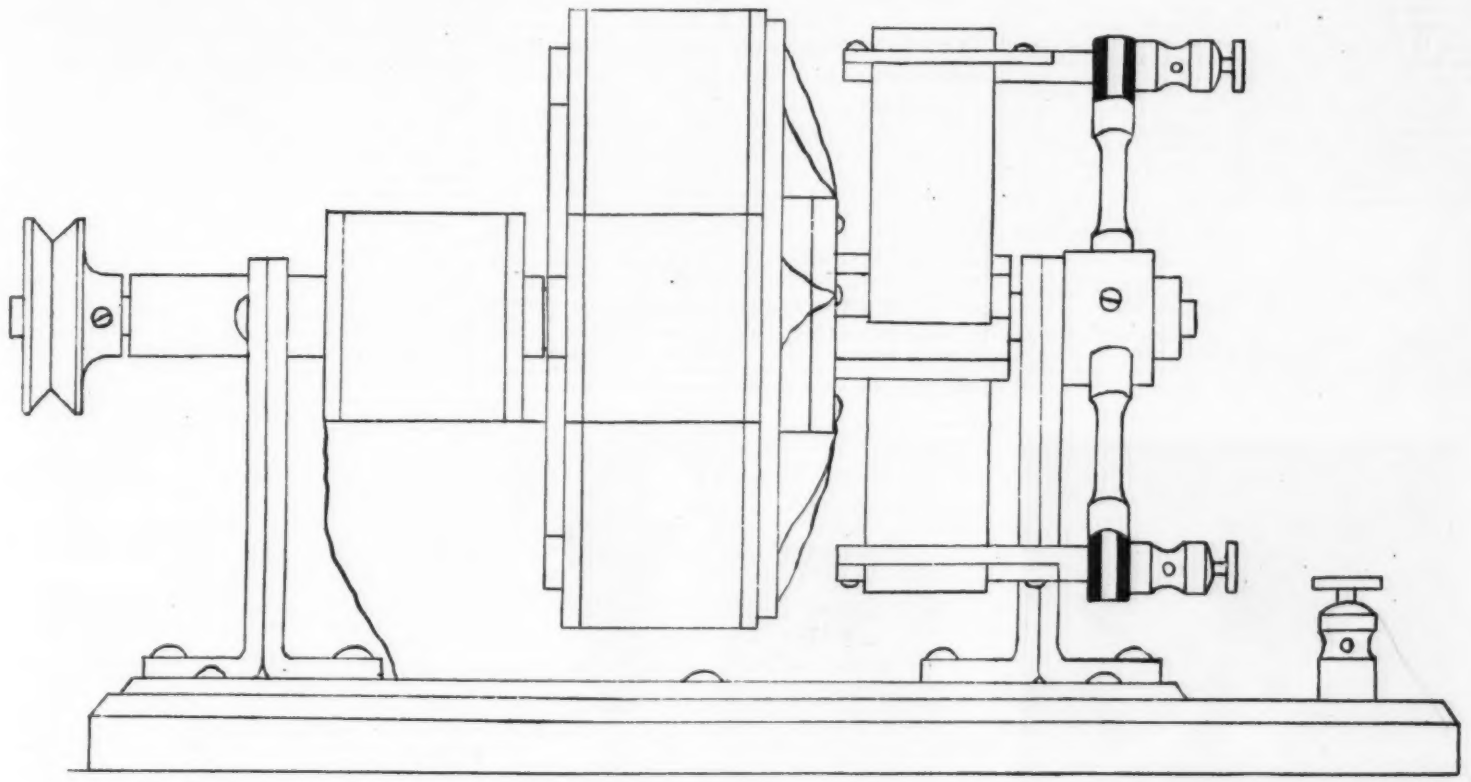
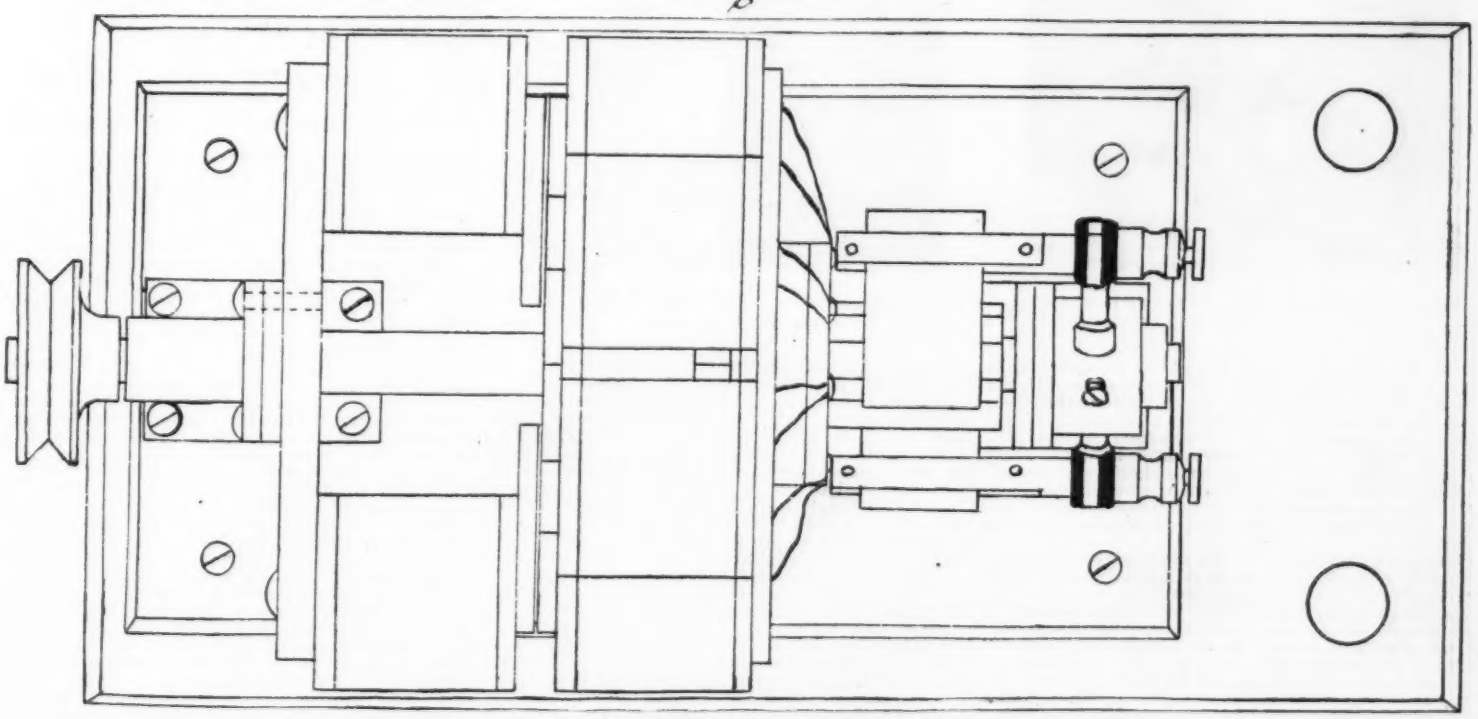


Fig. 12



HOME MADE ELECTRIC MOTOR.

writer has sewed through *eighteen* thicknesses of heavy drilling, using a light running Domestic sewing machine, and six *pint* cells of bichromate plunge battery, such as has been already described. The machine ran through those eighteen thicknesses with hardly any slackening of speed from running with two thicknesses, and it was running faster than one would care to have it run for ordinary family sewing, something like 500 stitches per minute. This speaks sufficiently for the power of the machine.

If one cares to experiment to improve upon the model, it is suggested that iron spool ends be substituted for those of wood or rubber. The cores can be made of the form shown in Fig. 10, and the iron disks be bored to fit, and be then securely fastened by riveting down the ends and finishing off smooth in an obvious manner. The iron pole pieces may possibly then be dispensed with, the iron spool ends taking their places.

However this may be, the amateur will here find a powerful and fairly efficient motor that requires no patterns or castings from which to be made. It was made by the writer as an experiment, from scraps about the house, with only a few tools and a turning lathe. It cost but little, cost of wire and all included, and it does its work in good shape. By careful work, by polishing and lacquering the brass standards, the bed plate and brush holder, and finishing the iron parts smooth and bright, a handsome motor will result, one that looks "shipshape and Bristol fashion." It is hoped, therefore, that this description may assist others desirous of building a motor in a simple way.

C. D. Parkhurst,
Lieut. Fourth Artillery.

ELECTRIC TORCH AT THE PARIS OPERA HOUSE.

We have already pointed out to our readers the numerous services rendered by electricity to the stage, which is always on the lookout for new and brilliant effects. We shall now speak of a recent application made in "Ascanio," the new work of Mr. Saint-Saens at the Paris Opera House. In the third act, in the mythological ballet, Phœbus appears among the Muses holding the torch of Genius in her hand (Fig. 1). This torch, of moderate size and elegant form, must be brilliantly lighted for from twelve to fifteen minutes every evening. The incandescent lamp skillfully concealed under colored gems could alone solve the problem. The question was to light this lamp easily without the use of conductors coming from an external source of energy.

Fig. 1.—PHŒBUS HOLDING THE TORCH OF GENIUS.

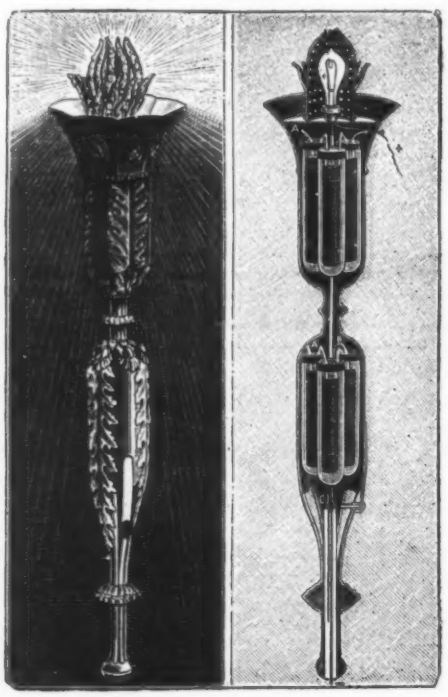


Fig. 2.—EXTERNAL AND INTERNAL VIEWS OF THE TORCH.

Messrs. Ritt & Gailhard, the directors of the opera, applied to Mr. Trouve, whose skill has no equal in the structure of electric jewels. Desiring to utilize the resources that were offered him by the central station of electric energy that supplies the opera house, Mr. Trouve constructed some small portable accumulators which are all placed in the torch. Fig. 2 gives an external view of the torch and an internal view, with the arrangement of the accumulators. These latter are six in number. The first three occupy the upper part of the apparatus, and the three others the lower part. They are of the Planté variety, and are formed of lead plates, five centimeters in height by seven in width, wound one around another. They have a surface of thirty-five square centimeters. The total active surface is about one square decimeter per element. Each of the elements is placed in the interior of a cylindrical case of thin glass, covered with sheet gutta percha. This receptacle is seven centimeters in height and two in diameter. Mr. Trouve has found that the distance to be allowed for the spacing of the polar plates is one and a half millimeters. With this figure he has been enabled to obtain a capacity that has permitted of supplying the torch for one or two representations. Each complete element weighs 70 grammes. The battery as a whole, therefore, weighs 420 grammes. The six accumulators are mounted in tension. They are capable of furnishing 10 volts and 3 amperes for fifteen or twenty minutes, say 30 watts for a third of an hour, or 10 watts-hour, or 1 ampere-hour. In the torch, the accumulators are, all six, mounted in tension upon the lamp, and the two wires that constitute the circuit descend parallel with each other to a point, C, which is the place where Phœbus grasps the torch. A small contact button is placed just above the two wires, so that, on the least pressure, the lamp is lighted, and is extinguished when the pressure ceases. Fig. 1 represents Miss Torri in her role of Phœbus. She holds the torch in her hand, and pressing the button with her thumb, causes the light to appear at will. The connections are arranged for facilitating the change. At the upper part is the positive pole, and at the lower, the negative one.—*La Nature.*

AN EXPERIMENTAL PROOF OF OHM'S LAW, PRECEDED BY A SHORT ACCOUNT OF THE DISCOVERY AND SUBSEQUENT VERIFICATION OF THE LAW.

By Alfred M. Mayer.

I purpose giving in this paper a simple and direct experimental proof of Ohm's law $\left(C = \frac{E}{R}\right)$ Generally a mere formal statement of this law with illustrations are given in text books on physics, and the student is left to infer that its truth is shown by the cumulative evidence given by the immense number of quantitative relations in electrical actions which the law associates, and by the experience that deductions made on the basis of this law agree in measure with the results of experiments. The latter fact is certainly one of the best proofs of the truth of the law; but, nevertheless, the relations between C, E and R are not directly and simultaneously shown to be exactly expressed by $C = \frac{E}{R}$ It is true that some works give experiments to show this relation, but they are so difficult to perform by reason of the difficulty of maintaining constant C, E and R, that the results of the experiments only approximate to those required by the law.

Ohm was led to the conception of this law by *assuming* that the flow of electricity in a voltaic circuit is similar to the flow of heat by conduction in a rod of indefinite extent. Also, his assumptions that the actions of two electrified particles are directly as their distance and that the electricity is uniformly dense over each cross section of a conducting wire were directly opposed to the laws and facts well established by Coulomb for statical electricity. It is not surprising that scientific men were slow in adopting the views and theory of Ohm. In his memoir (Die Galvanische Kette mathematisch bearbitet von Dr. G. S. Ohm, Berlin, 1827), he states:* "Three laws, of which the first expresses the mode of distribution of the electricity within one and the same body, the second the mode of dispersion of the electricity in the surrounding atmosphere, and the third the mode of appearance of the electricity at the place of contact of two heterogeneous bodies, form the basis of the entire memoir, and at the same time contain everything that does not lay claim to being completely established. The two latter are purely experimental laws; but the first, from its nature, is, at least partly, theoretical.

"With regard to this first law, I have started from the supposition that the communication of the electricity from one particle takes place directly only to the one next to it, so that no immediate transition from that particle to any other situate at a greater distance occurs. The magnitude of the transition between two adjacent particles, under otherwise exactly similar circumstances, I have assumed as being proportional to the difference of the electric forces existing in the two particles; just as in the theory of heat, the transition of caloric between two particles is regarded as proportional to the difference of their temperatures. It will thus be seen that I have deviated from the hitherto usual mode of considering molecular actions introduced by Laplace; and I trust the path I have struck into will recommend itself by its generality, simplicity, and clearness, as well as by the light it throws upon the character of former methods.

"With respect to the dispersion of electricity in the atmosphere, I have retained the law deduced from experiments by Coulomb, according to which, the loss of electricity in a body surrounded by air, in a given time, is in proportion to the force of the electricity and to a coefficient dependent on the nature of the atmosphere. A simple comparison of the circumstances under which Coulomb performed his experiments with those at present known respecting the propagation of electricity showed, however, that in galvanic phenomena the influence of the atmosphere may almost always be disregarded. In Coulomb's experiments, for instance, the electricity driven to the surface of the body was engaged in its entire expanse in the process of dispersion in the atmosphere; while in the galvanic circuit the electricity almost constantly passes through the interior of the bodies, and consequently only the smallest portion can enter into mutual action with the air; so that in this case, the dispersion can comparatively be but very inconsiderable. This consequence, deduced from the nature of the circumstances, is confirmed by experiment; in it lies the reason why the second law seldom comes into consideration.

"The mode in which electricity makes its appearance at the place of contact of two different bodies, or the electrical tension of these bodies, I have thus expressed: when dissimilar bodies touch one another, they constantly maintain at the point of contact the same difference between their electroscopic forces [potentials].

"With the help of these three fundamental positions, the conditions to which the propagation of electricity in bodies of any kind and form is subjected may be stated. The form and treatment of the differential equations thus obtained are so similar to those given for the propagation of heat by Fourier and Poisson, that even if there existed no other reasons, we might with perfect justice draw the conclusion that there exists an intimate connection between both natural phenomena; and this relation of identity increases the further we pursue it. These researches belong to the most difficult in mathematics, and on that account can only gradually obtain general admission; it is therefore a fortunate chance that in a not unimportant part of the propagation of electricity, in consequence of its peculiar nature, those difficulties almost entirely disappear."

From these premises, and guided by results of experiments made by him and by Ritter, Erman, Jäger, Davy and Becquerel, he arrived at the following conditions as existing in a voltaic circuit:

1. In a homogeneous conductor, forming part of a voltaic circuit, the difference of the electric tensions at any two points of the conductor is proportional to their distance.

2. In different conductors forming part of a circuit, the difference of tensions at two points separated by an interval equal to the unit of length is in the inverse ratio of the section of the conductor and of its coefficient of conductivity. Hence, in the different conductors, equal differences of tension correspond to lengths whose electric resistance is the same.

3. At the point of contact of two different conductors, there is a sudden variation of electric tension.

4. If A equals the sum of the electro-motive forces, L the resistances, λ the resistance reckoned from a point m of the circuit to a point p when the tension is zero, the tension at the point m is given by the formula

$$u = A - \frac{\lambda}{L}$$

Ohm eventually arrives at the formula $S = \frac{A}{L}$ which expresses what is generally known as his law. Which formula, he says, "is generally true, and already reveals the equality of the force of the current at all points of the circuit; in other words, it may be thus expressed: The force of the current in a galvanic circuit is directly as the sum of all the tensions, and inversely as the entire reduced length of the circuit, bearing in mind that at present by reduced length is understood the sum of all the quotients obtained by dividing the actual lengths corresponding to the homogeneous parts by the product of the corresponding conductivities and sections."

The words "tension" (*Spannung*) and "electromotive force" used by Ohm are the equivalent of the word *potential*. He was the first to introduce this conception into the theory of the voltaic circuit, and to the above words and to *current* and *resistance* he attached precise meanings and showed the relations existing between those quantities. The clear definitions Ohm gave of these terms marked a transition from vague ideas of "quantity" and "intensity" to the clear conceptions of potential, electromotive force, current, and resistance. The word *energy* he also used with clear and accurate meaning, as shown in the following statement: "That the decomposing force of the circuit is in direct proportion to the energy of the current, and, moreover, that it depends on a coefficient, to be derived from the nature of the constituent parts and their chemical equivalents." This was published in 1827, six years before Faraday's researches on electrolysis.

Neither Ohm nor his contemporaries were able to test the truth of the four statements given above as embodying Ohm's theory. It was reserved for Kohlrausch in 1849 to show by very ingenious and accurate experiments that Ohm's statements were true in mode and in measure. Kirchhoff† and Quincke‡ applied with success Ohm's theory to flow of electricity in thin conducting plates, or bodies of two dimensions, and the same was done by Smaasen, ‡ not only in a plane, but in bodies of three dimensions. The most remarkable confirmation of Ohm's law was made in 1876 § by experiments, suggested by Maxwell and performed by Chrystal in the Cavendish Laboratory, Cambridge, "in which the testing of this law seems to have been carried to the limit of experimental resources."

Though Ohm's law has thus received such ample verification that it ranks with the best established laws

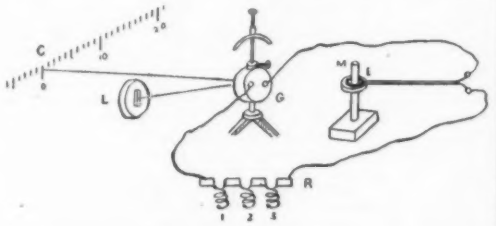
* See translation, published in vol. ii. of Taylor's Scientific Memoirs, p. 402. London, 1841.

† Pogg. Ann., t. lxiv, 1845, and t. lxvii, 1846.
‡ Pogg. Ann., t. xcvii, 1856.
‡ Pogg. Ann., t. lxiv, and t. lxxii.
§ Brit. Assoc. Rept., 1876, p. 36.

of nature, yet, as Maxwell says, "Ohm's law must, at least at present, be considered a purely empirical one. No attempt to deduce it from pure dynamical principles has as yet been successful. . . . The conduction of electricity through a resisting medium is a process in which part of the energy of an electric current, flowing in a definite direction, is spent in imparting to the molecules of the medium that irregular agitation which we call heat. To calculate from any hypothesis as to the molecular constitution of the medium at what rate the energy of a given current would be spent in this way would require a far more perfect knowledge of the dynamical theory of bodies than we at present possess It is only by experiments that we can determine the laws of processes of which we do not understand the dynamical theory."

Surely if an experiment, that is easily made, shows the truth of a law of such theoretical and practical importance as that of Ohm, even if it is one restricted in its range of C, E, and R, but shows within its limitations the relations $C = \frac{E}{R}$ then it should be made by all teachers of physics, so that clear physical conceptions of those relations may be given to students. As those who have seen these experiments have deemed them worthy of being more generally known, I now publish an account of them.

In the diagram the parts of the apparatus are shown, but not at their relative distances apart or in the proper proportions as to size. G is a low resistance Thom-



son galvanometer. At L is the condensing lens of a lime light lantern, which is covered with a cap having a rectangular opening in it. Across the middle of this slit is a vertical wire. The scale of the galvanometer is at C, distance 165 cms from the mirror of the galvanometer. The width of the divisions on this scale are 2·5 cms, and the lines are drawn 2·5 cms in breadth, or $\frac{1}{10}$ the distance apart of the centers of the lines forming a unit of the scale. The scale is at such distance from the galvanometer mirror that the image of the vertical slit just fits in the space of a scale unit, while the breadth of the image of the vertical wire is exactly equal to the breadth of a scale line. This arrangement gives the means of observing a deflection of the beam of light to $\frac{1}{10}$ and $\frac{1}{20}$ of a unit with quickness and accuracy.

The image of the slit is so bright and that of the wire so distinct that this method of observing deflections of the galvanometer may be used in broad daylight, and the deflections may be read throughout the room.

An incandescent electric lamp with a part of its surface (behind the plane of its filament) silvered may replace the lime light. Thanks to this arrangement, I have been able during many years to make before my class electrical measurements, and to measure the radiation, reflection, refraction, diathermancy and polarization of radiant heat.

At M is a magnet 25 cms long and 1½ cms in diameter. On this magnet slides a wooden disk. At R is box containing 1, 2 and 3 ohms of resistance, made of coils of copper wire.

An insulated copper wire wound at its middle in a circle of one coil, or in a spiral of any number of coils, is placed over the magnet and rests on the top of the wooden disk. The figure shows (one-half size) how

this circle of one coil is made. It is bent around a wooden cylinder 3½ cms in diameter, and then free ends of wire are bent one-half turn on each other. The free lengths of the wire are then lashed to a light square rod of wood as shown in figure. The wire and rod are then coated with shellac to cement them firmly together. Rings of spirals of 2, 3, 4, 5, 6 coils are also made in the same manner, but the coils are in a spiral, *i. e.* in one plane, and are then cemented together with shellac between rings of thin cardboard.

The length of wire forming each of these rings of spiral coils with the portion on its handle is one meter long.

The resistance of this length of wire added to the resistance of the lengths between it and G and R, together with the resistance of the galvanometer, is (for convenience) made one ohm.

It may be well here to speak of the adjustment of the galvanometer before describing the experiments, for I have noticed in some laboratories and lecture rooms galvanometers which are used not as they should be. I have noticed that the damping magnet formed a considerable angle with the plane of the coil. This was either because the median plane of the coil was not in the magnetic meridian or because there was considerable torsion in the suspending thread.

In these galvanometers, or, at least, in mine, the median plane of the coil is placed parallel to the faces of the drum of the instrument. The plane of one of these faces is brought in the magnetic meridian of the room, which has been carefully drawn on the table under the vertical center line of the galvanometer coil, by means of a long magnetic needle mounted like those used on plane tables. A line at right angles to this meridian is now drawn so that its point of intersection with the meridian line shall be exactly under the suspending thread of the mirror. In the vertical plane of the line, drawn at right angles to the meridian, is placed the vertical wire in the slit of the lantern, L, and also the zero line of the scale, C. The scale is parallel to the magnetic meridian. The galvanometer is now placed in the position given above and the "directing magnet" removed to a distance. The image of the vertical wire at L will now be found on the zero of the scale if there is no torsion in the suspending thread. If it does not come to zero, then the head of the rod to which the thread is attached is turned till image of wire coincides with zero of scale, and then the instrument is in adjustment, and it will give deflections as the tangents of the strength of current, or, in other words, the current strength will be directly as the readings on the scale. The magnet, M, is now placed so that it causes no movement of beam from the zero of the scale. The directing magnet, above the coil, is now so adjusted that the time of an oscillation of the magnets of the galvanometers is above five seconds.

The coil, E, over the magnet is put in the circuit of G and R. The wires between E and G and R are twisted and tied together so that no induced current from the earth's magnetism may be caused by the motions of this part of the circuit. The image of wire is on zero of scale. Now on rapidly lifting the coil from around the magnet a deflection is produced by the magneto-electric current thus generated. It is sufficient to know that the cause of this current is the quick lifting of the ring with one coil. If we replace this by a ring of two coils we get twice the deflection, and rings of 3, 4, 5, and 6 coils give 3, 4, 5, and 6 times the deflection given by the ring with one coil. Adopting the conception of the lines of magnetic force, we say that the ring with one coil cuts a certain number of these lines, this cutting of the lines causes the current, and is *the electromotive force*. The ring with two coils makes two cuts of these same lines, or cuts double the number of lines, the rings of 3, 4, 5 and 6 coils cut 3, 4, 5 and 6 times the number of lines, and hence give 3, 4, 5 and 6 times the electromotive force.

In these experiments the resistance of the circuit has remained constant. Now take the ring with 5 or 6 coils, and let us have one ohm as resistance of circuit. On lifting ring from magnet we get a certain deflection, which we may make exactly equal to a whole number of the units of the scale by sliding up or down the disk on the magnet. We now take out plug of resistance box and make resistance of circuit two ohms. The deflection of the galvanometer magnet now becomes one-half of that of previous experiment, and successively making the circuit with resistances of 3, 4, 5, 6, and 7 ohms we get $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, and $\frac{1}{7}$ of the deflection we got with one ohm in circuit.

When these experiments are made with the galvanometer in perfect adjustment, and with the precautions indicated below, the deflections arrive one after the other exactly as the law requires. Thus showing with sufficient precision for a lecture experiment that the current is directly as the electromotive force and inversely as the resistance. Indeed, generally the closest scrutiny does not detect in the scale reading any departure from the law.

Certain precautions are, however, necessary in these experiments. The resistance outside the galvanometer must be of copper wire, for such is the wire of the galvanometer. Also the whole of the apparatus must be put together the day before we make the experiments, and the room maintained at as constant a temperature as possible, so that the temperature of all parts of the apparatus is the same. The deflections should not exceed 15 divisions of the scale. Thus, if we start with 15 divisions of deflection for a resistance of one ohm, we will get 7·5 ; 5 ; 3·75 ; 3 ; 2·5 ; and 2·143 deflections for resistances of circuit of 2, 3, 4, 5, 6, and 7 ohms ; and if with a constant resistance we obtain a deflection of 2 divisions of scale with a ring of one coil, we will get deflections of 4, 6, 8, 10, and 12, with rings having 2, 3, 4, 5, and 6 coils.

It is necessary that the coils should be removed from the magnet *very quickly*, otherwise the deflections will not be as the law requires. In other words, the currents produced should be as instantaneous as can be obtained. Instead of rapidly removing the coils by the hand, I have sometimes lashed the coils and their handles to a spring board with a hole in it which went over the magnet. By a trigger this spring board is released. We thus get the same velocity in lifting the coil in each experiment. We have found, however, that the hand of a good experimenter gives precise results. Sometimes I have sent the coil from the magnet by the blow of a stick delivered on the under side of the handle of the coil at its center of percussion. There is no doubt some departure from the law in these experiments, for it is not possible in such experiments to obtain what is understood by instantaneous currents ; and the damping of the magnet by the mirror acting on the air must come into play. Yet I have never seen any but insignificant and barely discernible departures from deflections required by the law. This follows the small angles of deflections and low velocity of the motion of the galvanometer magnet in the experiments. It is also to be noticed that with a good magnet of the size stated, and with the galvanometer making one vibration in about 5 seconds, the coil with 5 turns pases over only 2 cms. or less of end of magnet in order that it shall give a deflection of 15 divisions of scale. It is evident that in these conditions a very short time is occupied in cutting the lines of force. If the maximum deflection used is 15 divisions of the scale, the actual angular deflection of the magnets and mirror amounts to only 6° 29′. Yet 15 divisions are quite a length on the scale, being equal to 37·5 cms. But these experiments may be as readily made with a ballistic galvanometer. Then the magnets and coils have to be of larger dimensions.

Experiments similar to those given have served to graduate galvanometers. We have here the means of sending definite amounts of currents through an ordinary galvanometer, and we may thus graduate its angular readings into their relative values in current. The damping of the galvanometer has, however, to be applied to the readings, and then the results may best be put in the form of a curve.

Stevens Institute of Technology, Hoboken, N. J.

—*Amer. Jour. of Science.*

WHEREVER iron or steel comes in contact with African teak wood, an oil contained in the latter prevents rusting, and this, as well as other valuable qualities, is leading to a great increase in its consumption. It is easily worked, but wears out tools rapidly, on account of the quantity of silex it contains.

THE USE OF ALLOYS IN ART METAL WORK.*

By Prof. W. C. ROBERTS-AUSTEN, C.B., F.R.S.

A FIT introduction to the kind of facts I shall have to bring before you is afforded by St. Gregory of Nyssa, who said, "How beautiful are the imitations of beautiful things, when they preserve visibly the impress of the prototype."† To deal with beauty of form in metal work would be quite beyond me, but it may be possible to bring before you some few facts concerning the coloring and texture of metals which would, I think, present themselves to any metallurgist who might consider the matter carefully. It is usual, at the present day, to think more of the form of metal work than either its color or texture, but the Roman artists did not neglect either even in the case of large works, as is shown by the description given by Pliny of a bronze statue of a dying lady, the tints of which were so arranged that the life appeared to be gradually receding from the extremities of the limbs. He also describes a metal statue in which the sculptor wished to represent cheeks suffused with blushes, a result which was obtained by inserting points of iron in the bronze, the atmospheric oxidation of the iron giving a ruddy tint to the features. Allusion has been made to these cases simply to show that special treatment of color and texture may be applied to large monumental works, and not merely to the smaller productions to which our attention will this evening be mainly directed.

At the outset you may be inclined to question whether an effort should be made to impart color—even natural or apparently natural color—to metal work, which ought to depend mainly on beauty of form. Such a view would, however, hardly survive an examination of some of the old Chinese bronzes, such as those to which I shall refer later, in South Kensington, or even the antique bronze statues, with the wide range of blues and greens which they have attained by age and exposure to atmospheric influences. Even if you admit that color may sometimes be advantageous, you may urge that servile imitation of the texture of one material in another cannot be legitimate art, and that point has been dealt with by Mr. Ruskin, with whose writings as a guide I have recently visited Florence, partly with this paper in view. He leads us into the church of Santa Croce, to the memorial slabs of the late fourteenth or middle fifteenth century work which adorn the pavement of the church. Many of you know well the tomb to which I refer, of which Mr. Ruskin‡ says : "The old man lies on a piece of embroidered carpet, protected by the relief. Many of the finer lines of this are almost uninjured ; in particular its exquisitely wrought fringe and tassels are nearly perfect." And he says : "If you kneel down and look long at the tassels of the cushion under the head, and the way they fill the angles of the stone, you will, or may, know from this example alone what noble decorative sculpture is, was, and must be from the days of earliest Greece to those of latest Italy."

Mr. Ruskin has carefully pointed out that the object of this rich adornment, and his words are the key to anything I may have to say, is merely accessory ; or, to quote the learned teacher again, he says : "No great sculptor from the beginning of art to the end of it ever carved, or ever will, deceptive drapery. A man who will carve a limb or a face never finishes inferior parts but either with a hasty or scornful chisel, or with such grave and strict selection of their lines as you know at once to be imaginative, not imitative. But if, as in this case, he wants to oppose the simplicity of his central subject with a rich background—a labyrinth of ornamental lines to relieve the severity of the expressive ones, he will carve you a carpet, or a tree, or a rose thicket, with fringes and leaves and thorns elaborately, as richly as natural ones, but always for the sake of ornamental form, never of the imitation, yet seizing the natural character of the lines he gives, with twenty times the precision and clearness of sight that the mere imitator has."

We see, therefore, the way in which the imitation of material, surface, or texture may be useful as an incident of the main composition, and it is in this sense that I intend to deal with it while showing how such enrichments may be produced. I do not propose to dwell on the use of either *niello* or mere encrustations of gold, silver, or copper, which the garments of figures of bronze often received at the hands of Greek and Roman sculptors. I would consider rather the actual imitation of the surface of other materials, such as wood or fabric in metal. Examples are rare in the best work of the Italian Renaissance.

In the gate of the Baptistry at Florence, Ghiberti does no more than suggest the actual texture of the fruit and flowers he uses with such perfect skill, blending them chiefly for the sake of loveliness of form. Nor, so far as I can remember, does Peter Vischer attempt to imitate the texture of leather in the metal apron of his own statue in the shrine of St. Sebald, at Nuremberg. On the other hand, in the best of the 15th and 16th century coins, which were of course not monumental work but coins, the fur and silk embroidery of the pontifical robes are often exquisitely and naturalistically rendered. Such treatment is especially well shown in the coins of Pope Innocent XII. and Pope Alexander VIII., by Hameranus.

The Japanese, however, are the real authorities to whom we must turn for guidance in the use and treatment of alloys, both in texture and color. First, as regards texture, they seem to delight in copying in metal work the most delicate texture; even the bloom on the surface of fruit is not beyond their admirable skill. In tracing the nature of their methods, it is necessary to repeat what has often been said by others and by myself respecting the alloys they employ in order to produce their wonderful results. There is a wide range of such alloys, but the principal of them are but few. There is an alloy of silver and copper, sometimes with equal proportions of precious and base metal, and there are endless varieties of copper of different degrees of purity.

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* A paper recently read before the Society of Arts, London, and published in the *Journal*.

† Quoted by Archdeacon Farrar, in the sermon preached at Liverpool, before the members of the National Association for the Advancement of Art, 1886.

‡ "Mornings in Florence, being Simple Studies in Christian Art."

There are several kinds of brass, of which I cannot at present give you the analyses, because they belong to the Department of Science and Art, and will shortly be published by authority. They have also a remarkable series of alloys, in which the precious metal replaces the tin and zinc of ordinary bronze; but really their main alloys, with the exception of bronze, are comprised in the following examples.

The first is called "shaku-do;" it contains, as you will observe from analyses I. and II.,* in addition

SHAKU-DO.

I.	
Copper	94·50
Silver	1·55
Gold	3·73
Lead	0·11
Iron and arsenic	traces
	99·89

II.	
Copper	95·77
Silver	0·08
Gold	4·16
	100·01

to about 95 per cent. of copper, as much as 4 per cent. of gold. It has been used for very large works. Colossal statues are made of it, one cast at Nara in the 7th century being specially remarkable. The quantity of gold is, however, very variable, and certain specimens I have analyzed contain only 1·5 per cent. of the precious metal. The next important alloy used by the Japanese is called "shibu-ichi," and the following are typical analyses:

SHIBU-ICHI.

III.	
Copper	67·31
Silver	32·07
Gold	traces
Iron	0·52
	99·90

IV.	
Copper	51·10
Silver	48·93
Gold	0·12
	100·15

There are many varieties of it, but in both these alloys, shaku-do and shibu ichi, the point of interest is that the precious metals are, as it were, sacrified in order to produce definite results, gold and silver, when used pure, being employed very sparingly to heighten the general effect. In the case of shaku-do, we shall see presently that the gold appears to enable the metal to receive a beautiful rich purple coat or patina when treated with certain pickling solutions, while shibu-ichi possesses a peculiar silver gray tint of its own, which, under ordinary atmospheric influences, becomes very beautiful, and to which the Japanese artists are very partial.

These are the principal alloys, but there are several varieties of them, as well as combinations of shaku-do and shibu-ichi in various proportions, as for instance in the case of kiu-shibu-ichi, the composition of which would correspond to one part of shaku-do rich in gold and two parts of shibu-ichi rich in silver.

With regard to the use of pickling solutions, so far as I have been able to ascertain, they are made up respectively in the following proportions, and are used boiling:

	I.	II.	III.
Verdigris	438 gr.	87 gr.	220 gr.
Sulphate of copper.	292 "	437 "	540 "
Niter	—	87 "	—
Common salt	—	146 "	—
Sulphur	—	233 "	—
Water	1 gal.	—	1 gal.
Vinegar	—	1 gal.	5 fl. dr.

That most widely employed is No. I. When boiled in No. III. solution, pure copper will turn a brownish red, and shaku-do, which, you will remember, contains a little gold, becomes purple. And now you will be able to appreciate the effect of small quantities of metallic impurity as affecting the color resulting from the action of the pickle. Copper containing a small quantity of antimony gives a shade very different from that resulting from the pickling of pure copper. But the copper produced in Japan is often the result of smelting complex ores, and the methods of purification are not so perfectly understood as in the West. The result is that the so-called "antimony" of the Japanese art metal workers, which is present in the variety of copper called "kuromi," is really a complex mixture containing tin, cobalt, and many other metals, so that a metal worker has an infinite series of materials at command with which to secure any particular shade; and these are used with much judgment, although the scientific reasons for the adoption of any particular sample may be hidden from him. It is strictly accurate to say that each particular shade of color is the result of minute quantities of metallic impurity, and these specimens and diagrams will, I trust, make this clear, and will prove that the Japanese arrange true pictures in colored metals and alloys.

The action of these solutions is remarkable. You have copper to which a small amount of silver and a small amount of gold are added. The amount of gold may be variable, and artificers often take credit for putting in much more than analysis proves to be present; but a small amount of gold, it may be only one per cent., is sufficient to entirely change the character of the copper, and when you come to treat it by pickling solutions, you get a totally different result from what you would if copper alone were employed.

The Japanese also take copper and dilute it, sometimes half copper and half silver, sometimes only about one-third silver and all the rest copper, and that gives the lovely series of gray alloys which, either by exposure to atmospheric influences, by handling, or by treatment of suitable pickles, gives the beautiful series of light and dark grays of which the Japanese are so particularly fond, and to which the name of shibu-ichi is given. Then again they have copper in which small amounts of impurities may be present, and the nature of such impurity and its amount, which seldom exceeds two-tenths per cent., is quite sufficient to change the character of the copper. The Japanese, working in no small measure by rule of thumb, find that certain varieties of copper are best suited for definite processes, and they store them up and use them in a definite way. I have here a diagram which shows the particular tints produced by pure copper when adulterated, so to speak, with under two per cent. of the elements indicated—bismuth, antimony, nickel, iron, arsenic, and gold. There is also a series in which the impurity is under two-tenths per cent., and when a pickling solution acts upon these metals you get these characteristic tints, the gold still holds its own, and produces the purple-blue alloy characteristic of the shaku-do, of which the Japanese make so much use.

Remember that in all these cases the precious metals were deliberately sacrificed with a view to produce a definite result, and that is a point I want to insist upon. Why cannot we, in this country, use the alloys (of which we have the analysis here) in order to produce results in these lovely gray tints with which so many of you are familiar? The finest piece of shaku-do that I know, with its blue bloom, is this beautifully carved sword hilt from the collection of Mr. Edward Dillon; and shaku-do forms the basis of many specimens of Japanese art. Here is a little medicine case (reproduced in a wall diagram); the base of the case is shaku-do, and, I should think, nearly of the composition given in analysis No. 1. The enrichments are the gray shibu-ichi, a kuromi fish, with 24 tiny dots of gold in the space of about one-eighth of an inch. Then there is a shibu-ichi shell, with a gold shell placed beside it, and a kuromi carrot, on which a gray shibu-ichi mouse, with shaku-do spots let into him, is feeding. All this lavish adornment is most perfectly done. The actual method of manipulation I will now describe.

Turn to this plate of light brown bronze (Fig. 1),

Fig. 1.

which presents the simplest possible case. There is no attempt at a raised surface; the artist has simply taken a plate of bronze, 8½ inches in diameter, he has cut a design in it, and inlaid that design with shaku-do. Wherever he has scooped out the drawing of this beautifully graceful bird, he has inlaid shaku-do; and he has taken a darker variety of shaku-do—that is to say, one which contains a little more gold, which, when treated with a suitable pickling solution, will come out a little darker—and has in that way produced exactly the effect of an Indian ink painting, in a dark and comparatively light shade, on a piece of glazed brown paper. There is no attempt at producing an effect by a raised surface, but the design is completed by an inlay of dark shaku-do on lighter shaku-do on a bronze basis. In this more precious case (Fig. 2) we have a larger plate, 18½ inches in diameter, which is, on the whole, a fair

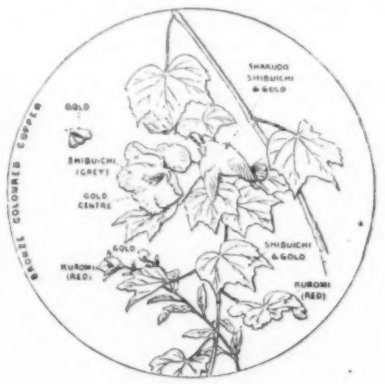


Fig. 2.

example of the treatment of the complex series of alloys, and it has been reproduced in a wall diagram with more or less success. They first of all take a plain surface of copper. In this case there is a raised ornament, instead of a perfectly flat one. They scoop out the outline of a leaf, undercut it to a certain extent, make the leaf that they wish to insert of a particular alloy—it may be shaku-do tipped with gold, the surface being roughened and the gold hammered on just as a dentist would—then the whole design is fitted in like a puzzle, and the result is they build up a picture gradually, using colored alloys, or alloys which may be colored by the action of a pickle, and they attain the result which is shown in the diagram. The basis is a plate of copper. Here in one place there is a leaf which is not really raised, but a little sunk below the surface of the original plate. The only relief it possesses is obtained by hammering a light variety of gold over it. Then comes a red bud of kuromi, set with its golden points. Here is a shibu-ichi leaf, half of which is of red kuromi, and if you look closely afterward you will see the bird, of shaku-do, with all his feathers carefully drawn, and the lustrous effect of the plumage produced with really consummate skill by the use of fine lines. Then comes a shibu-ichi flower with a golden center. This is typical of the work they do; however large or small it may be, they simply inlay these colored alloys, using generally a somber base.

The Japanese do not merely trust to obtaining effects by high relief, as is the case with this plate. Very often they employ a darker alloy for producing the effect of painting on metal, so to speak, in a very remarkable way. There is one example in Mr. Huish's collection, a knife handle, which presents the effect of a duck's back and wings in comparatively high relief with his neck under water (Fig. 3). He is a shaku-do purple

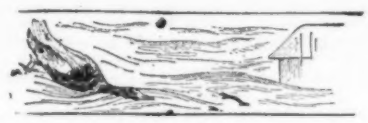


Fig. 3.

The diagram represents a portion of a Japanese knife handle in the collection of Mr. Marcus B. Huish. It consists of *Shibu-ichi*, an alloy containing about equal parts of silver and copper. The duck is of *Shaku-do*, the alloy of copper with from 1 to 5 per cent. of gold. By "pickling," a gray patina is given to the *Shibu-ichi*, and a purple patina to the *Shaku-do* duck, the arrangement being so skillful that the neck of the duck appears to be beneath the water, and is only seen when the handle is held toward the light in certain directions.

duck, plunging through silvery gray water, but his body is in high relief, his neck is of a different *nuance*, of tinted shaku-do to the rest of his body, and it is so beautifully let in that it is only in certain lights that you can see it all, but it produces exactly the effect of the duck's neck being below the surface of the water. I have not that specimen here, but I have in a sword hilt, also from the collection of Mr. Huish, some tiny minnows, each about $\frac{1}{8}$ of an inch, with minute gold eyes, swimming up a shibu-ichi gray stream, the effect of their being actually below the surface of the water being suggested with marvelous skill. I think at present no European artificer could obtain such a result as that, as it shows the most beautiful effects, not merely of texture, but brilliancy and transparency. The color effect they produce by the use of the pickles—the composition has been already given; but many of the extremely valuable old Chinese bronzes have acquired their tint simply by long exposure to atmospheric influences. If you look, for instance, at No. 160 in the South Kensington bronze cases, it is a Chinese duck of about 1 ft. across, if I recollect rightly, purchased about 1876, and it has a green patina, indicating extreme old age; and although my friend, Mr. Gowland, who has recently returned from Osaka, says the attribution of it on the label to the third century is inaccurate, still it is an extremely old specimen of bronze, which has acquired its green patina by perfectly natural causes, unaided by artificial treatment, such as the Japanese always employ in more modern work. Again, there is No. 148, a green gourd, in the South Kensington collection, and No. 79, a vase in the form of two cups, base to base, a beautiful mottled red on a green patina, and I think in this case the red is produced by heating and not by pickling. Then if you look at No. 224 in the museum, you will see a bronze fish with scales inlaid with silver, which is very instructive. In one of the cases, not very easily accessible, near the windows of the same court, there are a series of specimens of bronze plaques, all modern, showing the method by which the Japanese produce their effects. Here, on the wall, is a faithful diagram of a bronze plate which has been splashed with gold; it is really hammered work, and is grayish red bronze by daylight. There is also a clouded bronze, the effect of which I think has been produced by heating and not by pickling. On this diagram (Fig. 4) some of these effects are shown.

Here (*a*, Fig. 4) is a portion of an ordinary Chinese

Fig. 4.

bronze kettle, in which the ornament has been obtained by little punctures from behind which reflect the light. If you looked at this you would think at first there were two metals, a copper kettle inlaid with silver, but it is nothing but the effect of the polished surface of brownish copper, with raised prominences from behind to reflect the light and produce the effect of another metal; *c*, Fig. 4, is another example of similar ornament. Mr. Gowland has lent me, for the purpose of this paper, a splendid kettle, the heating arrangements of which are intended to go inside it, a sort of double kettle. You will see how very beautifully the surface is worked, and that the effect is produced entirely without any variation of color, for the tint is uniform throughout. Here is a characteristic brass, of which the surface is produced by simply striking it all over with a blunted tool, which gives these particular lines (*c*, Fig. 4).

But the particular alloys in which I am interested, and with which I hope to interest you, are those to which the names of moku-me (wood grain) and miyu-nagashi (marbled) are given. I have so often talked of them before, that I hesitate to describe them again.

* Analyses Nos. I. and III. are by Mr. Gowland, of the Imperial Japanese Mint at Osaka; Nos. II. and IV. by Prof. Kalischer, "Dingl. Polyt. Journ.," ccxv., 98.

The characteristic alloys which the Japanese employ are taken in thin sheets and soldered together—kuromi, shibu-ichi, and shaku-do—in alternate layers, as shown in the diagram (Fig. 5); then you drill conical

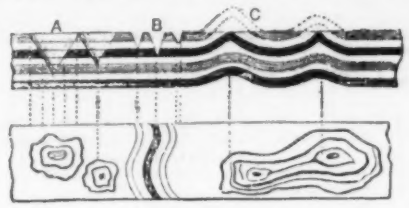


FIG 5.

holes, A B, in them to a greater or less depth, or roll them out, and then beat them up from behind, and then file off the prominences, C, and then beat the sheets until the holes are obliterated, and, of course, you get these different strata, and you produce these beautifully banded effects. Fig. 6 shows more accu-

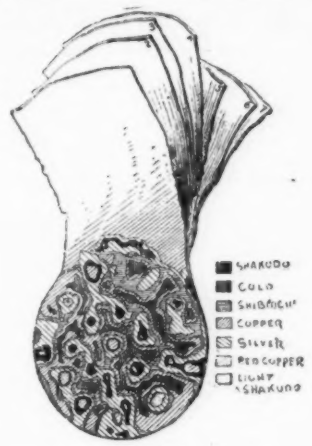


FIG. 6.

rately the method of actual work, the pattern being produced by beating up a seven-layered plate from behind, and filing the surface flat. If you look at the specimens afterward, you will see what the Japanese can do, for you have here the finest collection of mokume ever got together. There are two vases (one shown in Fig. 7), not very good in form, but of remarka-

FIG. 7.

ble merit as regards the manipulative skill displayed in their production; each vase is seven inches high. The neck band and foot are of shaku-do inlaid with gold, while the body of the vase is of miyu-nagashi, with a silver panel bearing a bird beautifully wrought in gold and colored alloys beaten into the silver. There are also some smaller sword hilts and knife handles, and a collection of beads, all remarkable examples of these banded alloys.

Two of these beads are shown in Figs. 8 and 9. Fig. 8 is a cylindrical bead about one-half inch high; half the cylinder is of the marbled alloy (produced as shown in Fig. 6), and the rest of the cylinder is made up of bands of red copper shaku-do and silver, beautifully soldered. Fig. 9 represents a wonderful piece of manipulation. It is a bead three-fourths of an inch in diameter; half the sphere is of gray shibu-ichi, and the rest is composed of very fine soldered plates, showing how perfectly the complex alloy may be worked, even into a rounded surface.

Fig. 10 represents a knife socket of alternate layers of copper and shaku-do, the effect of wood grain (mokume) being exactly imitated.

Now, so far as I know, no English artist has actually used this material with the exception of Mr. Alfred Gilbert, A.R.A., who, I rejoice to say, has employed it in the now famous chain worn by the mayor of Preston. But it is a beautiful material, that surely must be used by English art workmen if they hope to hold their own. The Americans have adopted it already, and in the Paris exhibition there was a very remarkable vase exhibited by Messrs. Tiffany, of New York. I have only a photograph of it here; but I have a little piece of their beautiful work in a little blade of miyu-nagashi. In the vase they exhibited, the top and sides are silver, and so is the base, but the whole of the center is of this marble alloy, produced exactly as I have indicated. This is some twenty-nine inches high, and they asked the modest sum of £1,000 for it. They only employed five alloys, I believe, in its manufacture, but I am not certain as to the number, doubled it on them-

FIG. 8.

selves five times until they ultimately got twenty-five layers. This beautiful vase certainly constituted one of the greatest triumphs of manipulative skill the Paris exhibition contained, and the firm were justly proud of it. Here is a little Japanese cigarette case of copper and shaku-do in many layers, in which solder cannot be detected at all, and yet it is a most complicated pattern. Messrs. Tiffany have even produced the celebrated Japanese "lobster red," which has quite eluded my efforts to secure. The lobster red of the Japanese is, I believe, not a product of pickling at all, but is cuprous oxide, formed by heating copper in air (it may be in air and steam, as is the case with their well known and brilliant colored commercial samples of metal), and then burnishing it, but I am not certain

FIG. 9.

about it. It is easy to match anything in this plate on the table, but it is difficult to produce the true lobster red of the Japanese.

Then, again, to leave Japanese art for the present, those who visited Tiffany's room in the Paris exhibition will have seen some very beautiful alloys which showed a beautiful purple tint. They were apparently of silver, and running over the object, which was usually small, a damask pattern in a darker shade of the same purple line. There was one coffee pot, I think some ten inches high; this had this beautiful damask-like ornament produced apparently by inlay, but yet it was not possible to see that there was any inlay. I believe the patina in this particular case was in some way produced by the action of light. We have tried

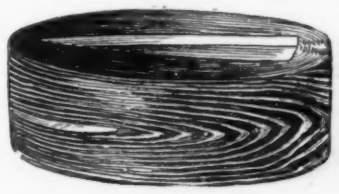


FIG. 10.

to throw some of these beautiful Japanese specimens on the screen, but I found the reflecting surfaces were too brilliant, it was impossible to succeed, and obviously we could not draw them, and therefore we must presently resolve ourselves into a committee to look at these things individually.

No texture seems to elude the skill of the Japanese. There is a knife handle, which represents gilded leather, from Mr. Gowland's collection, and there is a sword hilt from Mr. Dillon's collection, in which alternate layers of shaku-do and copper, some forty of them, have been cut through so as to form a pattern, and the result is a close imitation of guri or tsuishi lac, in the manufacture of which the Japanese are skilled. I have seen in Mr. Dillon's collection a fish in lustrous shibu-ichi, which was so beautifully rendered that it almost suggested a marine smell. Nothing seems too difficult for the Japanese craftsman. If you look at the band round the vase, represented in Fig. 7, at first sight you would think that it was real leather. Another very subtile effect they produce is by taking merely shaku-do in thin layers and ordinary silver solder, soldering them together, and then beating them up as I have shown in the diagrams (Figs. 5 and 6), and this is their finest work. I have only one tiny fragment of it, and it is produced by the contrast of the purple shaku-do with silver solder (Fig. 11). In their

FIG. 11.

very finest works they apparently use no solder at all, but simply trust to ordinary welding.

As an example of debased art, it is, perhaps, instructive to look at this article which I bought in Italy the other day; it is said to be manufactured near Milan. It is a little casket in pewter, probably marked with a revolving tool on a lathe, and the result is that if you look at it at a little distance, it has the most ludicrous resemblance to plush or thick satin, painted with thick body color to represent painting on satin. It is the most frightful example of misapplied skill you can well see. Still it is a close imitation of texture which might be applied to better things. Here are two little trays of quite cheap Japanese ware of copper bronze, which a botanist pronounced to be very faithful reproductions of a berried plant, and at once identified it as *Diospyros Kaki*. The skill with which the Japanese imitate the surface of the shells of crustaceans is well known, and, in fact, as I have already said, there is hardly any texture that they cannot imitate with wonderful fidelity if they care to try.

In Sir Frederick Leighton's presidential address, delivered at the Art Congress at Liverpool, he said: "Well what, then, is our charge with respect to the present relation of the country to art? What are the shortcomings for which we are here to seek a remedy? Our charge is that with the great majority of Englishmen the appreciation of art, as art, is blunt, is superficial, is desultory, is spasmodic; that our countrymen have no adequate perception of the place of art as an element of national greatness, that they do not count its achievements among the grounds of their national pride; that they do not appreciate its vital importance in the present day to certain branches of national prosperity; that while what is excellent receives from them honor and recognition, what is ignoble and hideous is not detested by them, is, indeed, accepted and borne with a dull, indifferent acquiescence; that the æsthetic consciousness is not with them a living force, impelling them toward the beautiful and rebelling against the unsightly."

I suppose that is true as regards the majority of Englishmen, but as the president of the Royal Academy points out, real merit is acknowledged; and the enthusiasm with which any piece of metal work of Alfred Gilbert is received, such as that grand table ornament which the army has recently given to the Queen, abundantly shows that a wide class of people will justly value really good work when they have a chance of seeing it. Any one who has had the privilege of seeing Gilbert's recent work must really feel lost in admiration of its beauty. Even people we should think uncultivated seem to feel singular interest in the good

FIG 12.

(a.) Image of Hanuman in copper and brass. The dark cross lines of the section of the figure (*b*) indicate the relation of the copper core to the investing layer of brass, which is marked with lighter section lines.

metal work that is shown in the Arts and Crafts Exhibition. But cannot we introduce these beautiful Japanese alloys? Why is not Mr. Gardner using them? Why is it left to a metallurgist to suggest what may be done in this respect? Here they are before you, and I

venture to think the metallurgists have done their part; we can tell you how to produce all these things with certainty, except, perhaps, the lobster red, and it remains for your artist to employ them.

In conclusion, I would say that many of these alloys may be blended by casting; you may have an alloy with a solidifying point a little lower than the rest, and pour the two alloys in succession, and the one which sets first may be covered by the other one. Here is an example of a bronze god (Fig. 12) clothed in brass, with brass anklets and bracelets. That is done by pouring brass round a copper casting of suitable form. On slicing this figure through, we found that was the fact. You have here the copper covered by the brass, and endless modifications may be produced in this way by pouring alloys one over the other.

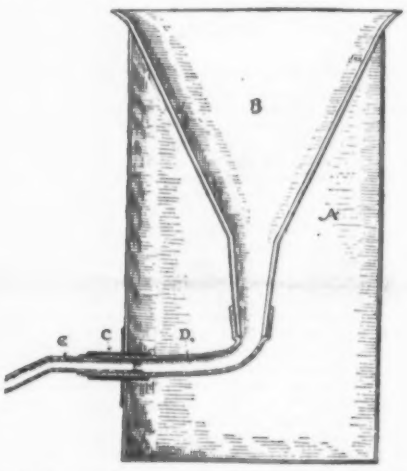
While this paper is passing through the press an excellent exhibition of metal work has been opened in the hall of one of the ancient companies of the City of London, the Armourers' and Braziers' Company. The works exhibited showed no lack of inventive power and careful design, notably in the case of the articles sent by the East-end "Guild and School of Handicraft," but the craftsmen limited their efforts to working in brass, copper, iron and the precious metals, and appeared to have no notion that a wide range of beautiful alloys were equally available. Surely an effort should be made to induce British artificers to employ the materials and methods which their Japanese brethren have used for centuries with such remarkable effect.

A CHEAP FUNNEL-JACKET.

By JOHN A. FORRET.

THE appliances in the market for keeping solutions hot while being filtered are a water-jacket of tin or copper, and a funnel let through the ordinary water-bath. With the tin-jacket there is no means of drying it after use, which means rapid corrosion by rust, while the copper article is too expensive. The only objection I have to the water-bath jacket is the large quantity of water to be heated when the bath is used for filtering alone.

Some time ago I devised the hot-funnel shown in section below, and find it to answer the purposes of a



A, tin box, round or square; B, funnel; C, brass tube, with collar soldered into A; D, I. R. tubing, stretched over funnel and fitting accurately into C; E, glass tube fitting tightly into D.

hot-water funnel-jacket. The funnel being in direct contact with the water, its contents are much more rapidly heated than in the case of the ordinary jacket, with its intervening tin or copper. One drawback, however, is its fixity when in use—the funnel cannot be removed without emptying the bath.

The whole thing can be put together in the back shop at the expense of a little time and patience. The one I have in use was made out of an old vaseline-tin, the brass tube being the neck of a disused spirit-lamp. —*Chemist and Druggist.*

WIBORGH'S METHOD FOR THE ANALYSIS OF SULPHUR IN IRON AND STEEL.

By J. B. COHEN, Ph.D.

THIS method, which has recently been published in detail in Professor Ledebur's new volume on iron and steel analysis (Leitfaden fur Eisenhutten-Laboratorien: Vieweg und Sohn), is described as rapid and accurate. The apparatus is shown in the figure.

It consists of a wide necked flask, *a*, of 250-300 cc.

capacity, to which is fitted a double bored cork. Through one hole passes a tap funnel, *b*, which terminates just below the cork, and through the other a cylindrical glass tube, *c*, about 21 cm. long, open at both ends. The upper end is about 6 cm. in diameter, and the lower end drawn out so as to pass through the second hole in the cork. The amount of sulphur is determined by the depth of the yellow stain produced by H_2S on the surface of a piece of calico previously soaked in a 5 per cent. cadmium acetate solution and dried, the calico being stretched across the wide open end of the cylindrical tube. The calico may be stretched by means of two stout India rubber rings ¼ inch in width, which fit tightly round the upper part of the wide tube. One ring is allowed to project above the tube, so as to form a horizontal edge, and over this the calico is stretched by means of the second ring. Ledebur employs a wooden ring and two clamps, but the above method answers perfectly well.

The flask is first half filled with water and boiled on a sand bath to expel air, the sample of iron or steel, 0·1 to 0·8 grm. according to the amount of sulphur, is quickly introduced, and the water again boiled for a few minutes; dilute sulphuric acid (1 : 5) is introduced from the tap funnel gradually until the iron is dissolved without interrupting the heating.

Sulphureted hydrogen is evolved and the calico is stained. To obtain an even stain it is necessary that the cylindrical tube should have a vertical position.

When the iron is completely dissolved, the boiling is continued for eight to ten minutes. The calico is now removed, well rinsed and dried, and the stain compared with a set of standard colors. The set of standards (six shades are sufficient) is prepared by taking a sample of iron with a known quantity of sulphur and obtaining various shades with different weights of the sample by the method described above. These should be mounted on white cardboard and kept for comparison.

Having made an analysis and fixed upon the standard shade which comes nearest to that of the sample, the weight of sulphur is determined by the following formula:

If w is the weight of the standard sample corresponding to the standard shade containing s of sulphur, and w_1 is the weight of the sample taken, then the weight of sulphur s_1 in the sample is

$$s_1 = \frac{w\,s}{w_1}$$

The same standard shade can therefore be used for a variety of samples when different weights are employed.—*Jour. Soc. Chem. Industry.*

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